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# MIDDLE DEVONIAN BRACHIOPODS OF SOUTHEASTERN WISCONSIN[1]

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ABSTRACT

Twenty-nine genera, forty-eight species, and five subspecies of brachiopods are recognized from the Middle Devonian formations of southeastern Wisconsin. Two species and four subspecies are new. The presence of *Trigonoglossa truncata* in the Wisconsin section seems to substantiate the extension of the range of this Pennsylvanian genus into the Middle Devonian as suggested by Girty, and the existence of well-preserved *Lingulidiscina* in the Milwaukee Formation supports the validity of this genus, previously questioned by Girty.

Correlation of the Lake Church formation is obscure because of incomplete collections from localities now inaccessible. However, distinctive Milwaukee Formation species show affinities with Upper Middle Devonian Cedar Valley brachiopods of Iowa, indicating the possibility of a connection between these areas during late Hamilton time.

The Wisconsin Devonian section is often omitted from discussions of Middle Devonian faunas and stratigraphy because of its limited extent and relatively obscure faunal relationships. The present work was initiated primarily to revise the brachiopod taxonomy and secondarily to confirm correlations with neighboring assemblages. Collections used in this work are mostly those acquired by Thomas A. Greene now housed at Milwaukee-Downer College, and by Gilbert O. Raasch, whose specimens are held by the Milwaukee Public Museum. My collecting was limited almost exclusively to the type locality of the Milwaukee Formation at Estabrook Park, Milwaukee, because expanding suburban development in the outcrop region has greatly reduced or eliminated most of the previously existing sites. The most recent taxonomic works were those of Cleland (1911) on the entire assemblage and of Pohl (1928, unpublished doctoral dissertation) on the pelecypods. Both of these indicate an Upper Middle Devonian age for at least the Milwaukee Formation. The stratigraphic sequence used as a basis for this work is that designated by Raasch (1935).

## PREVIOUS WORK

The narrow band of Devonian rocks exposed intermittently along 35 miles of Lake Michigan shoreline (fig. 1) remained undetected until 1860. At a Milwaukee Geology Club meeting, Increase A. Lapham reported fish remains from outcrops near Milwaukee. This was verified two years later by James Hall in a Report of the Geological Survey of the State of Wisconsin. This report represented the first systematic listing of a Devonian fauna from the State of Wisconsin. Serious collectors in the Milwaukee area in the late 19th century such as Charles B. Monroe, Edgar E. Teller, and Thomas A. Greene added greatly to the size and understanding of the Devonian fauna, which was extensively described for the first time by R. P. Whitfield (1882). The Devonian strata remained unnamed

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until 1906 when William C. Alden in the U.S. Geological Survey Milwaukee Folio (No. 140), described the section along the Milwaukee River at Estabrook Park, making this the type locality for the Milwaukee Formation. The most thorough taxonomic work was that done by Herdman F. Cleland in his report for the Wisconsin Geological and Natural History Survey (1911). The last extensive collections from the rapidly disappearing localities were those of Gilbert O. Raasch, made between 1928 and 1935 while he was a member of the staff at the Milwaukee Public Museum. The type locality for the lower portion of the Milwaukee Formation was in the quarries on the southwest side of the Milwaukee River and is now flooded. In addition, filling and park construction at Estabrook Park and along the lake front in Milwaukee have eliminated most of the upper, very fossiliferous beds. The type locality of the Lake Church Formation has also been flooded.

## METHODS

All brachiopod measurements were taken to the closest tenth of a millimeter whenever possible. For the purpose of photography, a magnesium oxide coating was used to highlight details on all specimens except the two terebratuloid forms which possess color markings. Serial sectioning was attempted on the terebratuloids, but the value of this procedure was limited because recrystallization and crushing had destroyed significant internal characters in most specimens. For this process, the terebratuloids were incased in a transparent casting plastic called "Castoglass." The mold for this work was a 3-inch section of 2-inch steel pipe with lathed perpendicular ends. This mold later served as a holding mechanism for the grinding process. The sections were taken at 0.5-mm intervals as measured by calipers. The plastic cast was held at these intervals by three set screws 1-inch from the base of the pipe. The sections were polished, etched, and stained as discussed by Cloud (1942). The peel solution was poured over the prepared surface and allowed to dry for 24 hr. These peels were transferred to slides and later traced by use of a microprojector.

Terms and abbreviations used in the systematic portion are explained as follows:

LATERAL FOLD PLICATION—The laterally bounding plications on each side of the fold.

FOLD WIDTH—The distance between the crests of the lateral fold plications.

FOLD HEIGHT—The distance from the adjacent trough to the crest of the lateral fold plication.

M.P.M.—Milwaukee Public Museum.

M.-D.C.—Thomas A. Greene Memorial Museum at Milwaukee-Downer College.

U.S.N.M.—United States National Museum.

The subnumbers used in conjunction with the catalogue numbers of the Milwaukee Public Museum for the terebratuloids and atrypids were designated by the writer, because several species were catalogued under the same number. The material from the Greene Collection was recorded only as being from Milwaukee. The appearance of the material and the exclusive presence of the Milwaukee Formation in the metropolitan area is considered adequate evidence for assigning this material to that formation.

## ACKNOWLEDGMENTS

I am indebted to Dr. Roger L. Batten for his initial suggestion and continued invaluable aid throughout the preparation of this paper. A thorough study of this fauna would not have been possible without the extensive collections and field notes of Gilbert O. Raasch. I wish to express my gratitude to the Milwaukee Public Museum for their unrestricted generosity in allowing me the use of this

material, especially Mr. Elmer R. Nelson, Curator of Geology, and Mr. Joseph G. Emielity for their cooperation and assistance. In addition, I would like to express my gratitude to Milwaukee-Downer College and its President, John B. Johnson, for making the Greene Museum collection available for study.

Special appreciation is expressed to Dr. G. Arthur Cooper of the U.S. National Museum for his help and suggestions. Also greatly appreciated was the opportunity afforded me by the American Museum of Natural History and the U.S. National Museum to study type material.

Thanks are also expressed to Mr. Robert W. Reyer for the generous loan of his personal Milwaukee Formation collection.

## STRATIGRAPHY

The Wisconsin Devonian consists of three formations, which reach a maximum thickness of 170 ft (Raasch, 1935). These formations, Lake Church, Thiensville, and Milwaukee, dip southeast and unconformably overlie the Silurian Racine dolomite. Outcrops and well log data indicate that the Lake Church Formation, which crops out north of Port Washington, pinches out 15 miles to the south near the Milwaukee-Ozaukee County line. The Lake Church, primarily a buff to brown, thick-bedded dolomite with all fossils found as casts, is divided into two members, an upper Ozaukee and lower Belgium, totaling 35 ft. The more fossiliferous Belgium Member, exposed only in the northern quarries, is no longer accessible because of flooding. The top 4 to 6 ft of the Ozaukee Member are exposed at localities 1 and 5.

The only good exposure of the Thiensville Formation is in a road cut on Wisconsin route 57, 2 miles north of Thiensville. This section exposes approximately 30 ft of poorly fossiliferous, mostly brown, hard, porous dolomite, which has a basal conglomerate where it directly overlaps the Racine dolomite.

The Milwaukee Formation (with a probable thickness of 80 ft) contains three members. The Berthlet (A and B zones of Cleland), is primarily a blocky, hard, gray dolomite with interbedded shale, and fossils in the form of casts. The overlying Lindwurm Member (C zone of Cleland), predominantly shale with a few hard, thin, dolomitic limestone units, has produced the greatest quantity and variety of fossils. The uppermost North Point Member is known only from now-inaccessible localities along the lake shore and from well logs. It is a black argillaceous shale and dolomite with a distinctive *Lingula* and *Chonetes* fauna.

Study of the available brachiopods of the Lake Church Formation leaves its correlation in doubt. However, a significant comparison was noted between brachiopods of the Milwaukee and the Cedar Valley Formations, which have been equated by other authors. Of the 46 species described from the Milwaukee Formation, 12 are also reported from the Cedar Valley Formation. Six other species have been reported in both areas, but their identification is questionable. In addition three new subspecies of Iowa forms are recognized in this paper. Cedar Valley brachiopods (including the species common to Wisconsin) are mostly larger, more robust, and bear a slightly more exaggerated surface ornament than Wisconsin specimens; however, an amazing morphologic affinity exists between the two faunas.

The following is a list of species and subspecies common to both the Cedar Valley and Milwaukee formations:

*Lingula milwaukeensis*
*Lingulidiscina marginalis*
*Orbiculoidea telleri*
*Strophodonta costata*
*Chonetes schucherti*
*Eosyringothyris occidentalis*
*Spinocyrtia iowensis*
*Athyris vitlata randalia*
*Cyrtina triquetra*
*Cyrtina umbonata*
*Cranaena subovata*
*Cranaena thomasi*

New Wisconsin subspecies of Iowa forms:

*Schizophoria iowensis musculosa*
*Pholidostrophia iowensis obscura*
*Tylothyris subvaricosa umbonata*

Questionable common forms:

*Orbiculoidea doria*
*Schizophoria lata*
*Pentamerella multicosta*
*Strophodonta halli*
*Atrypa pronis*
*Elytha subundifera*

LOCALITIES

*Locality 1.* (no. X40.1 of Raasch field notes) Flooded quarry 1.5 miles east of Lake Church near Lake Michigan, center of sec. 19, T. 12 N., R. 23 E., Ozaukee County, Wisconsin. Type locality of Lake Church Formation.

*Locality 2.* (no. X40.4 of Raasch) Road cut 2 miles north of Thiensville on Wisconsin route 57, NW¼ SE¼ sec. 10, T. 9 N., R. 21 E., Ozaukee County. Type locality of Thiensville Formation.

*Locality 3.* (no. X36.1 of Raasch) Flooded quarries and exposure on both banks of Milwaukee River at Estabrook Park, SW¼ NW¼ sec. 4, T. 7 N., R. 22 E., Milwaukee County. Type locality of Milwaukee Formation.

*Locality 4.* (no. X40.2 of Raasch) Abandoned quarry 1.5 miles north of Knellsville on County KW SE¼ NE¼ sec. 9, T. 11 N., R. 22 E., Ozaukee County. Lake Church-Racine contact 15 ft below top of quarry.

*Locality 5.* (no. X40.3 of Raasch) Flooded quarry 2 miles north of Thiensville, 0.25 mile west of locality 2, SE¼ NW¼ sec. 10, T. 9 N., R. 21 E., Ozaukee County. Lake Church-Racine contact 15 ft below top of quarry.

SYSTEMIC PALEONTOLOGY

Type specimens of new species are deposited in the Milwaukee Public Museum.

Phylum BRACHIOPODA
Subclass GASTROCAULIA Thompson, 1927
Order ATREMATA Beecher, 1891
Superfamily OBOLACEA Schuchert, 1896
Family OBOLIDAE King, 1846
*Trigonoglossa* Dunbar and Condra, 1932

Type species—*Lingula nebrascensis* Meek, 1872
*Trigonoglossa* Dunbar and Condra, 1932, Neb. Geol. Surv. Bull. 5, 2d ser. p. 35; Girty, 1939, U. S. Geol. Surv. Prof. Paper 193-C: 53.

Diagnosis: Generally subtriangular linguloid shells with nearly straight posterior lateral margins and flattened to broadly rounded anterior margin; central portion of shell slightly depressed; surface ornamented by sharp, raised, concentric ridges; broad flat interspaces marked by very fine growth lines and occasional radial striae.

Discussion: This genus was proposed by Dunbar and Condra for a group of externally distinctive Pennsylvanian inarticulates. Girty (1939), however, showed that there is such a great similarity between *Trigonoglossa* and such Devonian forms as *Linguella paliformis* and *Paleoglossa spatiosa* as to warrant either the extension of the range of *Trigonoglossa* or to re-evaluate the distinguishing characters of *Lingula*, *Lingulella*, *Paleoglossa*, and other similar linguloid shells in relation to *Trigonoglossa*. The characteristics of *Trigonoglossa* have not been sufficiently analyzed, therefore the specific and generic characters have yet to be clearly established. These genera also have been known to exhibit a subtriangular outline and notable concentric ornamentation. No internal or pedicle characters have yet been described for *Trigonoglossa* that would help clarify its generic relationships. The material from the Milwaukee formation appears very similar in ornamentation and shape to *T. nebrascensis* Dunbar

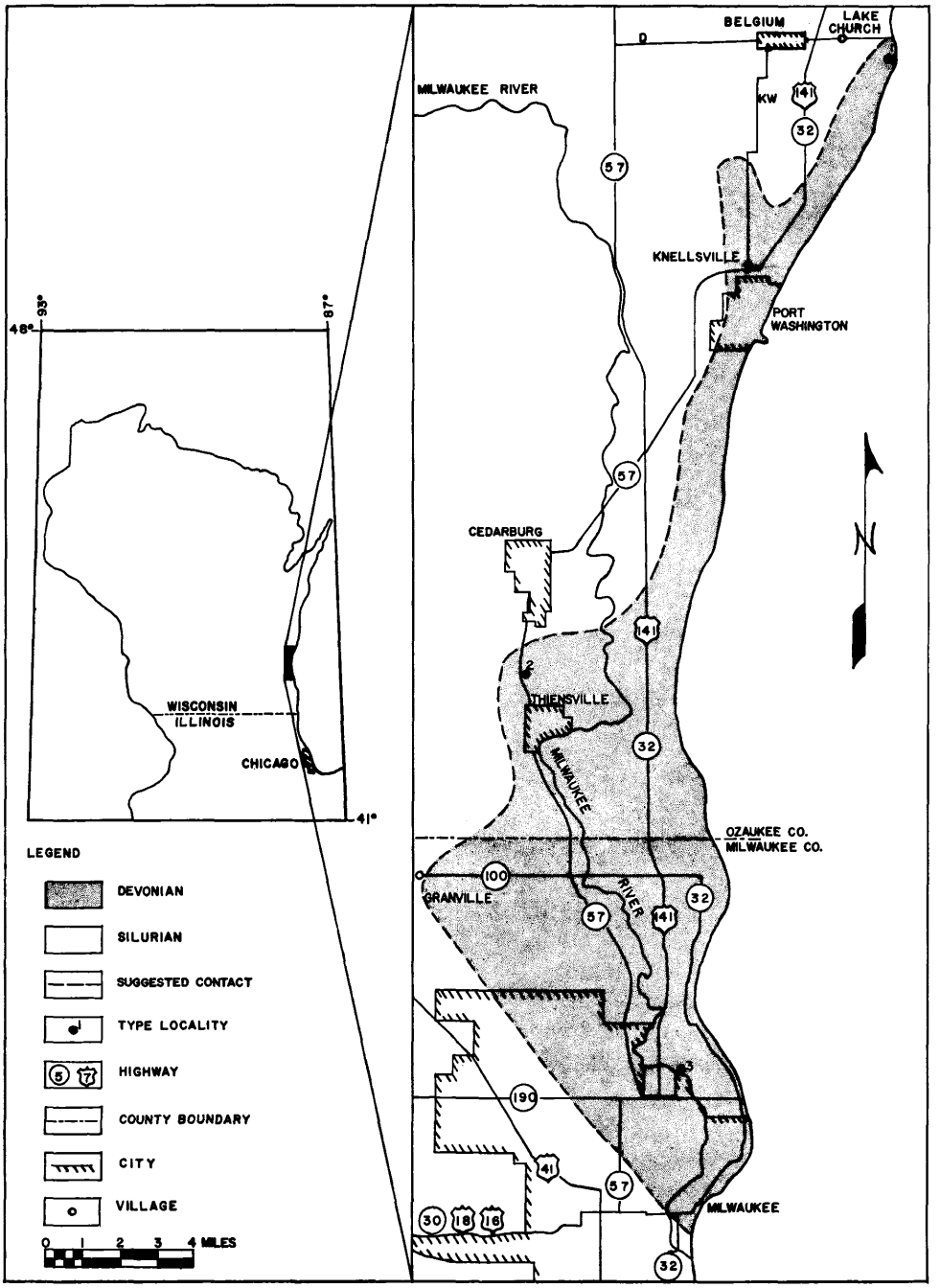


FIGURE 1. Outcrop area of the Wisconsin Devonian.

and Condra, 1932, the only apparent difference is that the Milwaukee species possesses fine radial striae that appear to be a specific rather than a generic character. On the basis of these specimens it is reasonable to extend the range of *Trigonoglossa* to the Middle Devonian, at least until study of additional material provides sufficient pedicle and internal characteristics to determine the taxonomic position of the Milwaukee forms.

Range: M. Devonian?—Pennsylvanian

### *Trigonoglossa truncata* (Cleland), 1911
Pl. 1, figs. 1, 2

*Lingula palaeformis* Whitfield, 1882, Geol. Wisconsin, 4: 324. pl. 25, fig. 10.
*Glossina truncata* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv., Bull. 21: 68. pl. 12, fig. 6.

Description: Shell average size for genus, longer than wide, subtriangular in outline; greatest width approximately three-quarters of length from apex; lateral margins slightly curved, forming broad apical angle; ornament indicates distinctly truncate anterior margin; center of shell slightly depressed; surface marked by strong, elevated, regular, concentric ridges, interspaces contain numerous fine growth lines; fine, radial folds distinct over length of shell.

Dimensions: Length 18–20 mm, width 15–17 mm, beak angle 70–85°; surface marked by 6–9 ridges per millimeter, striae between ridges 0.5–2 mm wide.

Discussion: The two specimens available for study show excellent external detail; however both are characterized by a truncate anterior margin and fine radial folds and striae. In addition to the comparisons noted in the generic discussion, the Wisconsin specimens also approach *Trigonoglossa flabellula* (Girty, 1939). *T. truncata*, however, has a more distinctly truncated anterior margin.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Two specimens from M.-D.C.—#4930, #5248.

## Superfamily LINGULACEA Waagen, 1885
## Family LINGULIDAE Gray, 1840
## *Lingula* Bruguière, 1797

Type species—*Patella unguis* Linnaeus, 1758
*Lingula* Bruguière, 1797, Encylopedie Methodique. v. 1, pl. 250; Hall and Clarke, 1892, Pal. New York. 8(1): 2.
Range: Ordovician—Recent

### *Lingula* cf. *L. complanata* Williams, 1882
Pl. 1, fig. 3

*Lingula complanata* Williams, 1882, Am. Assoc. Adv. Sci. 30: 188.
*Lingula complanata* Hall and Clarke, 1892, Pal. New York. 8(1). pl. 1, fig. 17.

Description: Large linguloid shell, ovate to subrectangular in outline; anteriorly subtruncate, posteriorly broadly rounded; lateral margins straight, slightly expanding toward anterior margin; greatest width anterior to midlength; shell nearly flat, beak depressed; surface marked by fine concentric growth lines.

Dimensions: Length 10.6 mm, width 6.6 mm, length width ratio 1.3:1.

Discussion: This species is represented by one specimen but is easily distinguishable from other linguloid shells by outline and relative convexity. The Wisconsin form is similar to *Lingula manni* Hall, 1867, in its flat appearance and general outline but differs in having more squared posterior lateral margins and considerably smaller dimensions. *L. compta* Hall and Clarke, 1892, also has the general flatness and squared appearance of the Wisconsin specimen, but differs considerably in having a higher length-to-width ratio, parallel lateral margins, and equally shaped anterior and posterior outlines.

Occurrence: North Point Member of the Milwaukee Formation at North Avenue Intake Tunnel, Milwaukee.

Catalogue specimen: One specimen from M.P.M.—#240.

## *Lingula milwaukeensis* Cleland, 1911

Pl. 1, figs. 4, 5

*Lingula milwaukeensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 69. figs. 3, 4.
*Lingula milwaukeensis?* Stainbrook, 1942, J. Paleontol. 16: 606.

Description: Shell small, subelliptical in outline; lateral margins curve gently, with termination of anterior and posterior margins somewhat sharp; highest at umbo, gently sloping toward anterior margin; surface marked by fine concentric growth lines paralleled by variously spaced color marked bands.

Dimensions: Average length 6.1 mm, average width 3.6 mm, length-width ratio 1.7:1.

Discussion: In specimen #239 of the Milwaukee Public Museum, a possible impression of a more elongated pedicle valve can be seen extending beyond the described configuration of the posterior margin for this species (plate 1, fig. 5). In general outline some of the shells show a more broadly rounded posterior margin and slightly less rounded lateral margins.

The Wisconsin species shows a slight similarity in general appearance to *Lingula spatulata* Hall, 1867, but is consistently larger and less pointed posteriorly than that form. *L. melie* Hall, 1867, is similar in size to the Wisconsin form, but is more rounded posteriorly and shows greater convexity.

Occurrence: North Point Member of the Milwaukee Formation at North Avenue Intake Tunnel, Milwaukee.

Catalogue specimens: Eleven specimens from M.P.M.—#236, #239.

## *Lingula rectilatera* Hall, 1859

Pl. 1, figs. 6, 7

*Lingula rectilatera* Hall, 1859, Pal. New York. 3: 156. pl. 9, figs. 6, 8.
*Lingula* c.f. *L. delia* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 70. pl. 12, fig. 1.

Description: Large shells, subelliptical to subovate in outline with broadly pointed to subangular posterior margins; lateral margins nearly parallel curving gently until approximately 3 mm from front of shell where margins begin curving sharply forming a broadly rounded anterior outline; shells moderately convex; suggested pedicle valve has greatest width slightly anterior to midlength; inner surface of shell shows distinct pallial markings; suggested brachial valve has greatest width slightly posterior to midlength; linear depression apparent from apex past midlength of shell, near anterior margin expressed only by disappearance of strong growth lines; space between ridges widens steadily toward anterior margin; some fine radial lirae near front of shell.

Dimensions: Pedicle valve average length 20.1 mm, average width 12.5 mm, length-with ratio 1.8:1, average beak angle 89°; brachial valve average length 17.4 mm, average width 10.3 mm, length-width ratio 1.7:1, average beak angle 111°; 10 concentric ridges per mm at umbo to 3 per mm near anterior margin.

Discussion: In plotting the posterior lateral margin configuration against various other characteristics, the seven available specimens divide into two distinct but closely aligned groups; however, surface ornament, size, and anterior lateral outline strongly indicate specific affinity. Rather than placing these more acuminate shells in a separate species, it is suggested they should be considered the pedicle valves of the more posteriorly blunted forms.

In general shape, the specimens described appear quite similar to *Lingula randalli* Girty, 1939, a species described from an unidentified horizon of upper Devonian near Warren, Pennsylvania; however, Girty's figures of *L. randalli* appear more rounded and show a less distinct surface pattern than the Wisconsin forms. *L. delia* Hall, 1867, shows a very similar outline, but differs considerably in size and has much finer ornamentation.

These large strongly ornamented linguloid shells are distinctly separate from any other brachiopod found in the Wisconsin section.

Occurrence: Milwaukee Formation, Estabrook Park, Milwaukee.

Catalogue specimens: Seven specimens from M.-D.C.—#5111, #5137.

## Order NEOTREMATA Beecher, 1891
## Superfamily DISCINACEA Waagen, 1885
## Family TREMATIDAE Schuchert, 1893
## *Lingulidiscina* Whitfield, 1890

Type species—*Lingula exilis* Hall, 1860
*Lingulodiscina* Whitfield, 1890, Am. Mus. Nat. Hist. Bull. 3: 122.
*Oehlertella* Hall and Clarke, 1892, Pal. New York. 8(1): 133, 168; Eleventh Ann. Rept. New York St. Geologist, 1892. p. 257.
*Lingulodiscina* Schuchert, 1897, U. S. Geol. Surv. Bull. 87: 260.
*Lingulidiscina* Girty, 1928, Wash. Acad. Sci. 18: 241–249.

Diagnosis: Transversely subcircular to circular outline; brachial valve slightly linguloid in appearance, subterminal to terminal beak, moderately depressed convex; pedicle valve characteristics discinoid, flat to slightly concave profile; brachial valve ornamented by moderate to fine irregular concentric growth lines, pedicle valve marked by regular, parallel, raised, concentric ridges.

Discussion: This genus proposed by Whitfield in 1890 was established to include a group of apparently unusual shells. The brachial valve is described as having a nearly terminal beak and irregular concentric ornament, but the pedicle valve has a nearly central apex and strong parallel surface markings. This seemingly strange combination of characteristics caused Girty (1928) to investigate the type specimens used by Whitfield in an attempt to determine the validity of the genus. His conclusion was that Whitfield's specimens were only "a somewhat unusual species of Orbiculoidea." In examining Whitfield's type material, Girty noted the poorly preserved nature of the shells. In discussing Whitfield's figures 1, 2, and 3, Girty concluded that lateral compression caused the destruction of the natural posterior outline, giving the brachial valve an unnaturally pointed appearance while leaving the pedicle valve with its original circular shape, relatively untouched. Girty apparently felt Whitfield was misled by this crushing, causing him to describe the shells as having "marginal or an

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EXPLANATION OF PLATE 1

FIGS. 1, 2. *Trigonoglossa truncata* (Cleland), 1911; 1, apparent pedicle view, Milwaukee Formation, locality 3, M.–D.C. #5248, ×1.8; 2, apparent pedicle view, from same formation, M.–D.C. #4930, ×1.8; p. 246.

3. *Lingula* cf. *L. complanata* Williams, 1882; broad view, North Point Member, Milwaukee Formation, M.P.M. #240, ×2.7; p. 246.

4, 5. *Lingula milwaukeensis* Cleland, 1911; 4, apparent brachial view, North Point Member, Milwaukee Formation, M.P.M. #236, ×5.5; 5, apparent pedicle view with extended pedicle beak, from same member, M.P.M. #239, ×5.5; p. 247.

6, 7. *Lingula rectilatera* Hall, 1859; 6, apparent brachial view, Milwaukee Formation, M.–D.C. #5173, ×1.3; 7, apparent pedicle view with extended pedicle beak, from same formation, M.–D.C. #5111, ×1.3; p. 247.

8, 9. *Lingulidiscina marginalis* (Whitfield), 1882; 8, brachial view showing marginal proximity of beak, Milwaukee Formation, M.–D.C. #5594, ×1.8; 9 interior pedicle view, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #228, ×1.8; p. 250.

10, 11. *Orbiculoidea* cf. *O. doria* (Hall), 1867; 10, interior pedicle view with exterior of brachial valve adhering along margins, North Point Member, Milwaukee Formation, M.P.M. #226, ×3.6; 11, brachial view showing radial ornament, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #15180, ×3.6; p. 251.

12. *Orbiculoidea* aff. *O. newberryi* (Hall) 1867; brachial view, Milwaukee Formation, locality 3, M.–D.C. #5584, ×1.8; p. 251.

13–15. *Orbiculoidea telleri* Cleland, 1911; 13, 15, brachial and lateral views, Berthlet Member; Milwaukee Formation, locality 3, M.P.M. #227, ×1.8; 14, interior pedicle view from same locality, M.P.M. #21727, ×2.7; p. 252.

16, 17. *Orbiculoidea* sp. A; 16, 17, lateral and brachial views, Milwaukee Formation, M.–D.C. #5627, ×1.3; p. 252.

18. *Petrocrania* cf. *P. hamiltoniae* (Hall), 1867; interior pedicle view, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #233, ×1.8; p. 254.

19, 20. *Petrocrania* aff. *P. inflata* Cooper, 1956; 19, 20, brachial and lateral views, Milwaukee Formation, M.–D.C. #5094, ×1.8; p. 255.

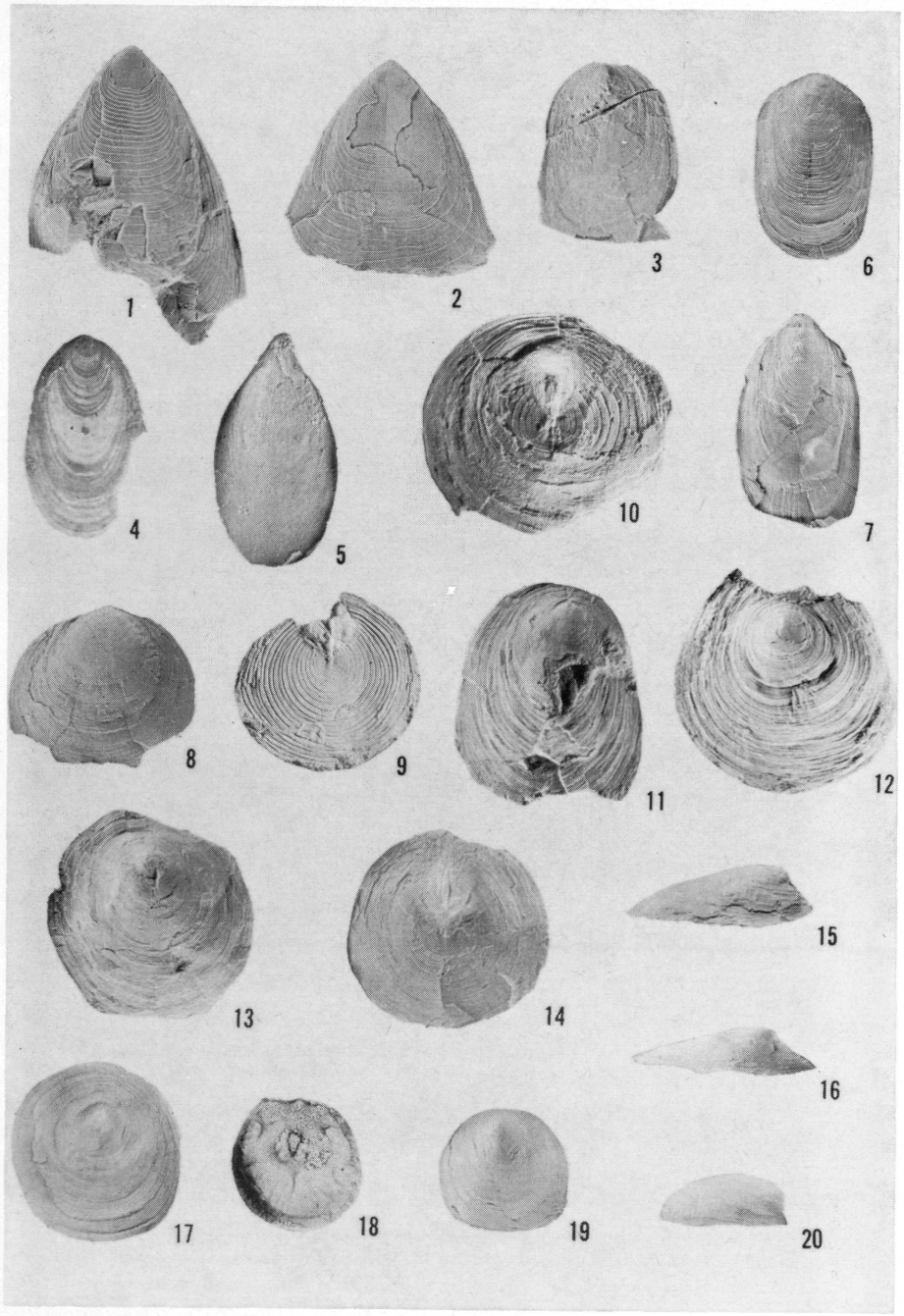


Plate 1

essentially terminal beak." Girty further questions the apparent lack of ornament on the brachial valve comparable to that described for the proposed pedicle valve. He suggests that, as on some orbiculoideas, the variation in sculpture could be due to a deterioration and eventual obsoleteness of the concentric lirae toward the margins on the brachial valve, and in conjunction with this genetic deterioration, the macerated condition of the type material could obscure any ornament that may have existed originally. The excellently preserved material from the Milwaukee Formation, which was verified as being a species of *Lingulidiscina* by Charles Schuchert (Cleland, 1911), shows the brachial valves definitely to have subterminal to terminal beaks, naturally fine concentric ornament and nearly circular outlines. In general configuration, the Milwaukee forms do parallel orbiculoideas, especially in the nature of the pedicle valve. The slit apparently is not marginal as in *Oehlertella*, a suggested synonym of Lingulidiscina; however, no clear description of the pedicle area was given by Whitfield, hence the taxonomic value to the pedicle characteristics is still obscure. The Milwaukee material seems to lend some support to Whitfield's generic diangosis especially in reference to the position of the brachial valve beak; therefore, until additional study can determine the generic importance of the brachial valve configuration and the pedicle slit characteristics, it seems justifiable to retain *Lingulidiscina* in reference to the Milwaukee specimens.

Range: M. Devonian

## *Lingulidiscina marginalis* (Whitfield), 1882
Pl. 1, figs. 8, 9

*Discina marginalis* Whitfield, 1882, Geol. Wisconsin. 4: 325. pl. 25, fig. 11.
*Lingulodiscina marginalis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 84. pl. 12, figs. 11–13.
*Lingulodiscina marginalis* Stainbrook, 1942, J. Paleontol. 16: 606. pl. 88, figs. 43, 45, 46.

Description: Moderate to large shells, subround to suboval in outline, pedicle valve slightly longer than wide, brachial valve slightly wider than long; shell profile dorsi-convex to convexo-concave; beak subterminal to terminal, pointing posteriorly; pedicle valve ornamented by strong, fairly regular concentric ridges, secondary fine growth lines between ridges, origin of shell growth slightly posterior to midlength; pedicle foramen extends from apex toward posterior margin; callosity subrectangular; brachial valve ornamented by fine, irregular growth lines, occasionally pronounced; greatest convexity slightly anterior to apex; umbo broad, gently sloping toward lateral and anterior margins, posterior lateral and posterior margins slightly concave; radial striations present along margins in some specimens.

Dimensions: Pedicle valve average length 19.2 mm, average width 18.8 mm, 1–3 concentric ridges per mm, foramen averages .9 mm wide, 4.9 mm long, extends between apex and point 3.5 mm from posterior margin, callosity 4 mm wide, 1 mm high; brachial valve average length 18.9 mm, average width 19.7 mm, average height 2.6 mm, 3–4 concentric growth lines per mm, average distance from beak to posterior margin .8 mm.

Discussion: The specimens studied ranged in size from 5 to 27 mm long and showed other minor variations but remain very similar in general appearance. The pedicle valves were almost invariably longer than wide, yet the brachial valves reverse this ratio. This reverse in the length-width ratio of the two valves is hidden in dorsal view as the brachial valve overlaps the pedicle valve on all margins by 1–3 mm. *Lingulidiscina marginalis* is easily separated from other Wisconsin Devonian inarticulates by its broad flat umbo and nearly terminal beak on the brachial valve and the complete reversal of length to width ratios for both valves as compared to orbiculoid shells.

*Orbiculoidea telleri* which is most similar in size and surface ornament to *Lingulidiscina marginalis* in the Wisconsin section, has a conical brachial valve, with a stronger, more centrally located beak, and a typically weaker orbiculoid callosity on the pedicle interior surrounding the slit. *O. doria* has a nearly terminal beak on occasion, but can be distinguished from *L. marginalis* by its development of distinct radial lirae.

Occurrence: The Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Twenty-six specimens from M.P.M.—#228, and M.-D.C.—#5594.

## Family DISCINIDAE Gray, 1840
## Subfamily ORBICULOIDEINAE Schuchert and LeVene, 1929
## *Orbiculoidea* d'Orbigny, 1847

Type species—*Orbiculoidea forbesi* Davidson, 1848
*Orbiculoidea* d'Orbigny, 1847, Compt. Rend. Acad. Sci. Paris. 25: 269; Prodome de Paleontologie Stratigraphique. 1: 44; Hall and Clarke, 1892, Pal. New York. 8(1): 125; Girty, 1928, Wash. Acad. Sci. 18: 128–142.
Range: Ordovician—Permian

### *Orbiculoidea* cf. *O. doria* (Hall), 1867
### Pl. 1, figs. 10, 11

*Discina doria* Hall, 1867, Pal. New York. 4: 19. pl. 2, figs. 19–22.
*Orbiculoidea doria* Schuchert, 1897, U. S. Geol. Surv. Bull. 87: 278.
*Orbiculoidea wardi* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 85. pl. 12, figs. 14–16.

Description: Shell moderately small; rounded to subovate in outline; dorsi-convex to convexo-concave in lateral profile; beak subterminal, shell slopes gently toward anterior, margins slightly flattened at commissure, which may be related to crushing; pedicle valve wider than long; apex just anterior to midlength, pedicle slit slightly raised; shell flat to slightly concave; brachial valve longer than wide; broad umbo, beak pointing posteriorly, shell depressed convex, greatest height at umbo; surface on brachial valve marked by fine to moderate, fairly regular growth lines, occasionally becoming slightly lamellose; fine radial lirae cross growth lines becoming very distinct in concentric striae causing checkered appearance; pedicle valve marked by regular, strong, raised, concentric growth lines, fine radial lirae noted on interior of shell.

Dimensions: Average length brachial valve 7.6 mm, average width 7.0 mm, average height 1 mm; pedicle valve foramen extends from apex to point 2–3 mm from posterior margin, foramen 0.6 mm wide; 8–15 growth lines per mm, 18–20 radial lirae per mm at anterior margin; pedicle valve marked by 3–4 concentric ridges per mm near apex, 12–20 radial lirae per mm near margin.

Discussion: Cleland (1911) established *Orbiculoidea wardi* with some of the specimens used for the present study of this assemblage; however, careful comparison of the Wisconsin forms with a topotype of *O. doria* (Hall), 1867, identified by Hall, shows a significant similarity in configuration, size, and surface ornament. There is considerable variation in the forms examined in such areas as strength of surface ornament and degree of roundness of shell outline. The smaller specimens tend to have a more regular and distinct concentric ornament, and usually a greater density in radial lirae; however, with the limited material available, the establishment of a separate species is not believed warranted.

The shells can be easily distinguished from *Orbiculoidea telleri* by the development of radial lirae and from *Lingulidiscina marginalis*, which has similar beak characteristics, by its stronger concentric growth lines and radial lirae. The smaller shells bear a resemblance to *Schizocrania*; however, the possession of a distinct orbiculoid pedicle valve in seemingly related specimens nullifies this possibility.

Occurrence: Berthlet, Lindwurm, and North Point Members of the Milwaukee Formations at Estabrook Park and the North Avenue Intake Tunnel respectively, Milwaukee.

Catalogue specimens: Eight specimens from M.-D.C. and M.P.M.—#226, #15180.

### *Orbiculoidea* aff. O. newberryi (Hall), 1867
### Pl. 1, fig. 12

*Discina newberryi* Hall, 1867, Pal. New York. 4: 25. pl. 1, figs. 10, 11.
*Oehlertella newberryi* Hall and Clarke, 1892, Pal. New York. 8(1): 132. pl. 4f, fig. 18.
*Orbiculoidea newberryi* Herrick, 1895, Geol. Ohio. 7. pl. 22, figs. 11, 13.
*Lingulodiscina newberryi* Schuchert, 1897, U. S. Geol. Surv. Bull. 87: 261.

Description: Moderately large shell, brachial valve only, greatest width anterior to midlength; subovate in outline, posterior lateral margins nearly straight, taper posteriorly;

slightly depressed conical shape, slopes gently toward front of shell; surface ornamented by very fine to moderate growth lines, occasional strong concentric lirae, all markings become heavier near margin, fine radial folds extend from margin three-quarters of distance from margin to apex, radial folds on underlying layers also.

Dimensions: Brachial valve 19 mm long, 17.6 mm wide, 3 mm high, apex 5 mm from posterior margin; every fourth to sixth growth line stronger.

Discussion: This distinctive shell shows a measurable resemblance to *Orbiculoidea telleri*, but differs in being more ovate in outline and in having more distinctive surface markings. It is similar also to *O. sp. A* of the Wisconsin section, but is differentiated from that form by having a more regular concentric and radial ornament. This Wisconsin form bears a general resemblance to *O. media*, but differs considerably in having much stronger ornament and a much more convex shell.

A search for the type specimen of *Orbiculoidea newberryi* proved unsuccessful. However, many of the characteristics described and pictured by Hall indicate a strong resemblance to the Wisconsin form.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimen: One specimen from M.D.C.—#5584.

## *Orbiculoidea telleri* Cleland, 1911
## Pl. 1, figs. 13–15

*Orbiculoidea telleri* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 85. pl. 12, figs. 9, 10.

Description: Moderate to large shell, subovate to round in outline, posterior margin sharply rounded; slightly convexi-concave in profile; beak strongly subterminal; pedicle valve slightly convex to concave; wider than long, somewhat raised pedicle slit; surface marked by strong regular concentric growth lines with interspaces two to three times width of ridges; brachial valve distinctly conical in profile; apex posterior to midlength, pointing slightly toward rear to shell; valve slopes gently toward anterior, increases in sharpness along posterior lateral margins, margins show no marginal flattening; shell longer than wide; surface ornamented by medium to fine slightly regular, crowded concentric growth lines, some specimens possess short radial lirae along margins.

Dimensions: Pedicle valve foramen 3.8 mm long, 0.5 mm wide beginning at apex extending 1.5 mm anterior to rear of shell; brachial valve average length 13.6 mm, average width 12.8 mm, average height 3.5 mm.

Discussion: Although these shells vary considerably in size, the general brachial valve configuration remains the same. A very significant ratio develops between the height of the shell and the distance of the beak from the posterior margin; it averages slightly more than a 1:1 ratio. This ratio characteristic separates this species from *Orbiculoidea* sp. A as is indicated in the discussion of that form. There appears to be some variation in the profile of the pedicle valve from convex to concave. This seems to indicate the ability of this encrusting form to adapt to the form of its host; however, flat to concave specimens are most common.

*Orbiculoidea lodiensis* Hall bears some similarity to the Wisconsin material in size and general outline. However, the flat brachial valve, more elliptical outline, distinctly convex pedicle valve lacking strong concentric growth lines, and the presence of external radial lirae separate *O. lodiensis* from *O. telleri*. *O. media* Hall approaches *O. telleri* in size and strength of surface ornament; however, the subelliptical shape, convex pedicle valve, and the more central brachial apex distinguish the New York from the Wisconsin forms.

Occurrence: Berthlet and Lindwurm Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Sixteen specimens from M.-D.C. and M.P.M.—#227, #21717.

## *Orbiculoidea* sp. A
## Pl. 1, figs. 16, 17

*Orbiculoidea telleri* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 85.

Description: Moderately large shell subovate to round in outline; brachial valve depressed, conical; apex posterior to midlength pointing slightly toward rear of shell; anterior

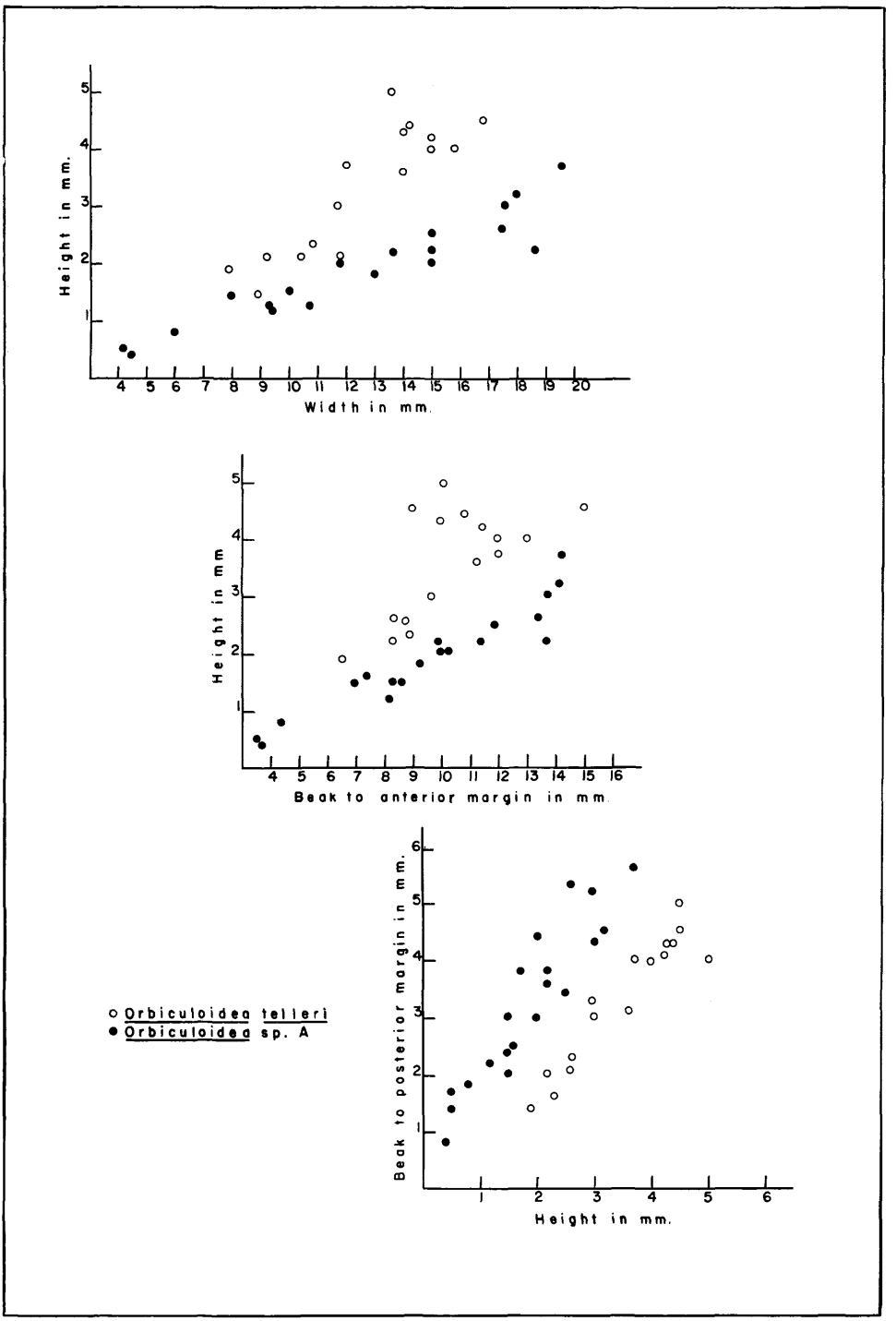


FIGURE 2. Scattergrams indicating significance of height in separating *Orbiculoidea telleri* and *Orbiculoidea* sp. A.

and lateral slopes very gently convex, posterior slope slightly concave, possibly due to crushing; shell longer than wide; surface ornamented to fine somewhat regular growth lines which become more pronounced near margins, short radial lirae evident on lower half of shell, no marginal flattening.

Dimensions: Average length 12.6 mm, average width 12.4 mm, average height 1.9 mm.

Discussion: The placing of these shells into a distinct group is based mainly on brachial valve height in relation to other external measurable characteristics. In studying the large collection of shells previously referred to as *Orbiculoidea telleri*, it became evident that they could be divided into two distinct groups on the basis of valve height versus distance from beak to the posterior margin. In *O. telleri* this ratio is 3.5:3.0; however, in what was referred to as a variation of *O. telleri* by Cleland (1911) this ratio becomes 1.9:3.2. When various measurements from the two groups are plotted, a significant specific variation becomes distinguishable. When using height as one of the variables, only in the height-width scattergram was any mixing (11.4%) noted (fig. 2). This distinct assemblage is not given a specific name at this time, because an attempt to locate the holotype of *O. seneca* (Hall), 1867, which seems to compare favorably with the Wisconsin material, was not successful.

There is a slight variation within this group in the prominence of the growth lines, and on occasion a regular pattern develops with a more pronounced ridge occurring every fourth to fifth line. Some specimens show marginal flattening, but this is due at least partially to crushing.

Occurrence: Berthlet and Lindwurm Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Twenty specimens from M.P.M. and M.-D.C.—#5627.

## Superfamily CRANIACEA Waagen, 1885

## Family CRANIIDAE Gray, 1840

### *Petrocrania* Raymond, 1911

Type species—*Craniella meduanensis* Oehlert, 1888

*Craniella* Oehlert, 1888, Soc. Etudes Scientif. d'Angers, p. 37; Hall and Clarke, 1892, Pal. New York. 8(1): 153.

*Petrocrania* Raymond, 1911, Carnegie Mus. Ann. 7: 229; Cooper, 1956, Smithsonian Misc. Coll. 127(1): pub. 4253: 287.

Range: M. Ordovician—Permian?

### *Petrocrania* cf. *P. hamiltoniae* (Hall), 1867

Pl. 1, fig. 18

*Crania hamiltoniae* Hall, 1867, Pal. New York. 4: 27. pl. 3, figs. 17–23.

*Craniella hamiltoniae* Cleland, 1911, Wis. Geol. and Nat. His. Surv. Bull. 21: 86. pl. 12, figs. 7, 8.

Description: Internal cast of pedicle valve; shell average size for genus; subround in outline, slightly longer than wide; lateral and anterior margins smoothly rounded, posterior margin straight or gently curved; moderately convex in lateral profile; internal structure shows two large indistinct muscle scars at extremities of posterior margin, central callosity posterior to midlength; median depression extends from central callosity toward front of shell; thickened slightly rounded shell edge evident on all margins except posterior; pallial markings distinct on lateral and anterior margins.

Dimensions: Length 10.0 mm, width 10.4 mm, height 1.2 mm; central callosity 2.5 mm from posterior margin, median depression 2.5 mm long; thickened margin 1.5 mm wide.

Discussion: The above analysis is based on two considerably recrystallized internal casts, which makes a positive identification unwarranted until additional material is uncovered.

Occurrence: Berthlet Member of the Milwaukee Formation from the type locality at Estabrook Park, Milwaukee.

Catalogue specimens: Two specimens from M.P.M.—#233.

### *Petrocrania* aff. *P. inflata* Cooper, 1956
Pl. 1, figs. 19, 20

*Petrocrania inflata* Cooper, 1956, Smithsonain Misc. Coll. 127(1): 288; pt. 2, pl. 25, I, figs. 24, 25, pl. 25, J. figs. 26–35, pl. 26, F, figs. 14, 15.

Description: Cast of interior of brachial valve; average size for genus; subround in dorsal outline, greatest width posterior to midlength; apex points posteriorly, overhangs slightly; highest portion of shell anterior to apex, posterior slope concave from apex to margin; fine concentric growth lines evident; very slight sulcus extends from anterior margin toward apex.

Dimensions: Length 10.5 mm, width 10.7 mm, height 4.4 mm, greatest height 2.5 mm from posterior margin; beak 0.6 mm from posterior margin; slight sulcus extends 2 mm posteriorly from front of shell.

Discussion: The close affinity this Wisconsin form has to *Petrocrania inflata* Cooper, 1956, from the Oklahoma Ordovician section, emphasizes its simplicity of character and easy adaptability. It seems quite possible that this form is actually the brachial valve of *P.* cf. *P. hamiltoniae*; however, its similarity with the Ordovician form cannot be ignored, at least until further material is found.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: One specimen from M.-D.C.—#5094.

## Subclass PYGOCAULIA Thompson, 1927
## Suborder DALMANELLOIDEA Moore, 1952
## Superfamily DALMANELLACEA Schuchert and Cooper, 1931
## Family SCHIZOPHORIIDAE Schuchert and LeVene, 1929
## Subfamily SCHIZOPHORIINAE Schuchert and LeVene, 1929
## *Schizophoria* King, 1850

Type species—*Orthis resupinata* Martin, 1809

*Schizophoria* King, 1850, The Permian Fossils of England. p. 105, 106; Hall and Clarke, 1892, Pal. New York. 8(1): 211–213; Schuchert and Cooper, 1932, Mem. Peabody Mus. Nat. Hist. 4(1): 143, 144. pl. 23, figs. 11, 16–18, 20–25.

Range: L. Devonian (Boucot, personal communication)—Permian

### **Schizophoria iowensis musculosa** subsp. n.
Pl. 2, figs. 1–4

*Schizophoria impressa* Whitfield, 1882, Geol. Wisconsin. 4: 326. pl. 25, figs. 13–15.
*Schizophoria striatula* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 93, 94. pl. 19, figs. 1–6.

Description: Moderate to large shells; broadly circular to subelliptical in dorsal outline, very slight wings developed at cardinal extremities, anterior margin slightly curved to flattened; dorsi-biconvex, greatest convexity at umbo of both valves, anterior commissure forms broad low undulation, becomes more exaggerated in larger shells; pedicle valve slightly convex, flattens gently toward thin margins; front of shell bears shallow sulcus; beak extends beyond brachial valve, cardinal area broadly triangular and concave, delthyrium narrowly triangular; strong central muscle scar, triangular in shape, outlined by strong socket plates, becomes strongly bilobate forming diductor impressions, divided anteriorly by strong median septum which narrows posteriorly equalling more than half of length of scar; brachial valve strongly convex, slopes evenly in all directions, moderate muscle scar broadly triangular, bilobate, weak short median septum between lobes; surface marked by rounded freely bifurcating costae; concentric growth lines become slightly crowded near anterior margin, very fine secondary fila between major growth lines.

Dimensions: Average length 25.1 mm, average width 29.9 mm, average height 15.4 mm; 12–14 costae per 5 mm near anterior margin, 5–10 concentric growth lines on brachial valve; holotype #16435—length 25.5 mm, width 30 mm, height 15.7 mm.

Discussion: *Schizophoria iowensis musculosa* can be separated from *S.* cf. *S. lata* in the

Wisconsin section because of its greater convexity, more elliptical shape, finer radial costae, and more crowded growth lines. Most variation noted seems closely related to the age of the shell; the larger shells have more lamellose concentric markings and an increasingly exaggerated sulcate commissure.

The dorsal outline, pedicle muscle field shape, and the strength of the median septum show a definite relationship to *Schizophoria iowensis* of the Iowa section. The Wisconsin form varies from *S. iowensis* in having a slightly narrower, and more sharply defined pedicle muscle field, and a more extended median septum. *S. iowensis musculosa* is very similar in general appearance to *S. mesacarina* Imbrie, 1959. However, the Wisconsin form has no well developed anterior median ridge in the pedicle valve and is less elliptical in outline.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.-D.C. and M.P.M.—#16435, #20445, #20446.

## *Schizophoria* cf. *S. lata* Stainbrook, 1940
## Pl. 2, figs. 5–7

*Schizophoria lata* Stainbrook, 1940, Am. Mid. Natur. p. 488–489. pl. 2, figs. 1–7, 15, 16.

Description: Moderate size shells for genus; subquadrate to elliptical in dorsal outline, cardinal extremities form slight wings, lateral margins regularly rounded to nearly straight anterior margin; nearly equally biconvex in lateral profile, greatest convexity at umbos of both valves; anterior commissure very slightly sinuate; pedicle valve moderately convex; beak suberect, delthyrium moderately triangular; cardinal area concave, broadly triangular, obtuse to nearly perpendicular to hinge line; brachial valve moderately convex; brachial beak extends slightly below hinge line; surface ornamented by rounded freely bifurcating and intercalating costae crossed by fine concentric nonlamellose growth lines, occasionally slightly exaggerated.

Dimensions: Average length 17.8 mm, average width 15.3 mm, average height 8.1 mm; 7–8 costae per 5 mm at anterior margin.

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EXPLANATION OF PLATE 2

FIGS. 1–4. **Schizophoria iowensis musculosa** subsp. n.; 1, 2, brachial and anterior views of holotype, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16435, ×0.9; 3, interior brachial view, Berthlet Member, from same locality, M.P.M. #20445, ×0.9; 4, interior pedicle view, Berthlet Member, from same locality, M.P.M. #20446, ×0.9; p. 255.

5–7. *Schizophoria* cf. *S. lata* Stainbrook, 1940; 5–7, brachial, anterior, and lateral view, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16436, ×1.3; p. 256.

8–10. *Gypidula* cf. *G. papyracea* Belanski, 1928; 8, 9, anterior and lateral views of pedicle valve, Belgium Member, Lake Church Formation, M.P.M. #19043, ×1.3; 10, pedicle view, from same member, M.P.M. #15031, ×1.8; p. 258.

11, 12. *Pentamerella multicosta* Cleland, 1911; 11, 12, lateral and pedicle views, Milwaukee Formation, M.-D.C. #4928, ×1.3; p. 259.

13–15. **Pholidostrophia (Pholidostrophia) iowensis obscura** subsp. n.; 13, interior brachial view, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16352, ×1.8; 14, 15, pedicle and lateral views of holotype, from same locality, M.P.M. #5021, ×1.8; p. 260.

16–19. **Protoleptostrophia serrata** sp. n.; 16, interior pedicle view, Lindwurm Member Milwaukee Formation, M.P.M. #321, ×0.9; 17, interior brachial view, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #C541, ×1.3; 18, pedicle view of holotype, from same locality, M.P.M. #16297, ×0.9; 19, enlargement of surface ornament, M.P.M. #16297, ×4.5 p. 260.

20. *Strophodonta* cf. *S. costata* Owen, 1852; pedicle view, Milwaukee Formation, Reyer collection #A–32, ×1.8; p. 261.

21–25. *Strophodonta halli* Cleland, 1911; 21, 22, 25, lateral, posterior, and pedicle views, Lindwurm Member, Milwaukee Formation, locality 3, writer's collection #A–36, ×0.9; 23, interior brachial view, from same locality, M.P.M. #310, ×0.9; 24, interior pedicle view, Berthlet Member, from same locality, M.P.M. #10987, ×0.9; p. 262.

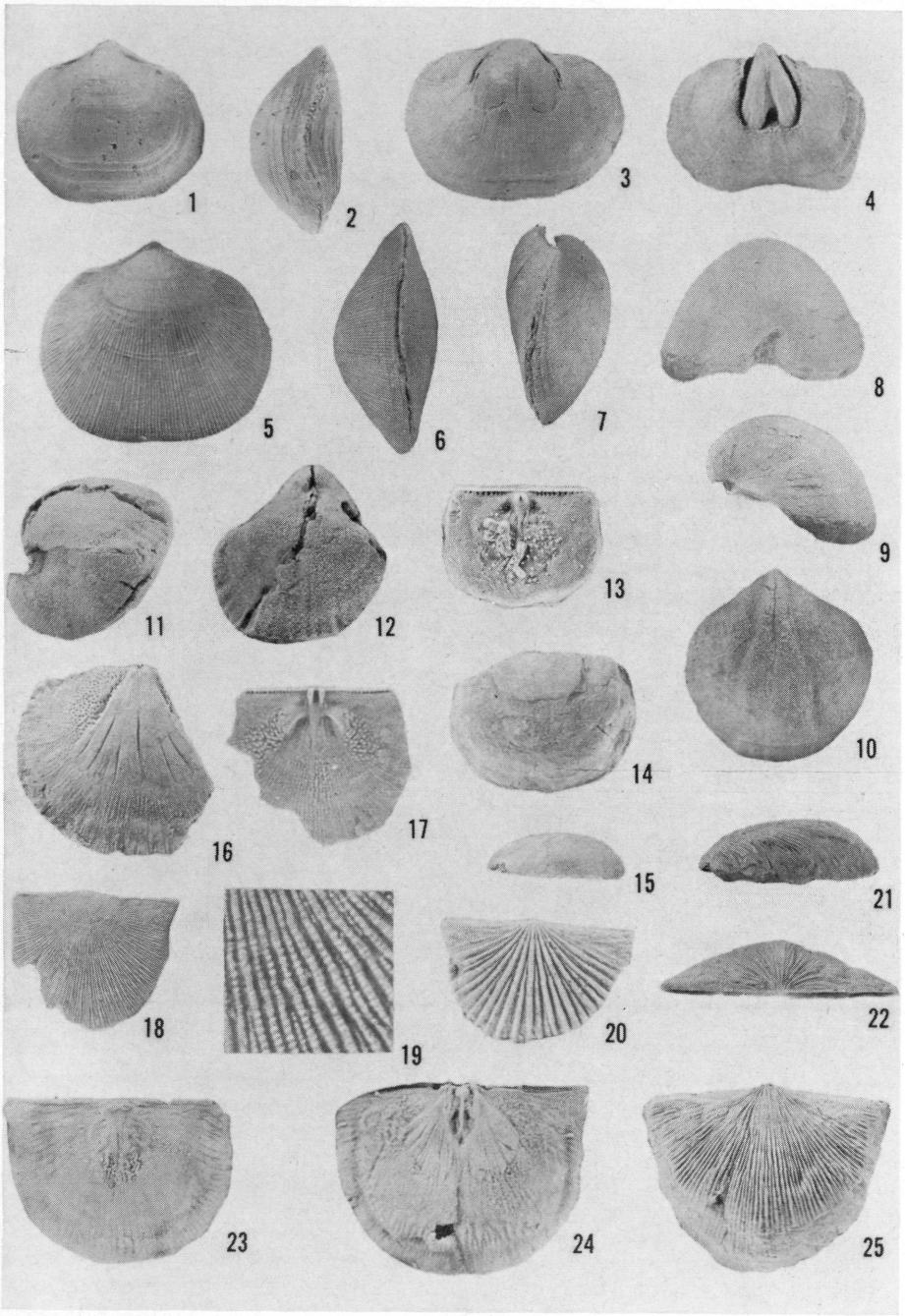


Plate 2

Discussion: These forms are most easily distinguished in the Wisconsin material by their flat appearance, and their stronger radial yet weaker concentric oramentation. The shells vary in the degree of their quadrate outline, occasionally appearing very elliptical, and in the angle between the cardinal area and the hinge line.

In general appearance *Schizophoria* cf. *S. lata* is similar to *S. mesacarina*, but has no sulcus development and is thinner than that form. This Wisconsin species is very similar to *S. striatula australia* (Kindle, 1909) in general appearance and outline; however, *S.* cf. *S. lata* has a more prominent beak, a higher cardinal area, and finer costae than that New Mexico form. *S. lata* from Iowa appears to be generally more elliptical than quadrate, larger, and slightly more coarsely costate than its otherwise very close Wisconsin representative; both forms are moderately convex and show little emphasis on concentric growth lines.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.P.M.—#16436.

## Suborder PENTAMEROIDEA Schuchert and Cooper, 1931
## Superfamily PENTAMERACEA Schuchert, 1896
## Family PENTAMERIDAE McCoy, 1844
## Subfamily GYPIDULINAE Schuchert and LeVene, 1929
## *Gypidula* Hall, 1867

Type species—*Gypidula typicalis* Hall, 1867

*Gypidula* Hall, 1867, New York St. Cab. Nat. Hist., 20th Ann. Rep. p. 163; Hall and Clarke, 1894, Pal. New York. 8(2): 241–247. pl. 72, figs. 15–24; Schuchert and Cooper, 1932, Mem. Peabody Mus. Nat. Hist. 4(1): 173–178. pl. 26, figs. 18, 22–24, 26–29, 31, 32, 34–40; Amsden, 1953, J. Wash. Acad. Sci. 43: 140, 141.

Range: M. Silurian—U. Devonian

### *Gypidula* cf. *G. papyracea* Belanski, 1928
### Pl. 2, figs. 8–10

*Gypidula comis?* Cleland, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 95, 96. pl. 19, figs. 7–9.
*Gypidula papyracea* Belanski, 1928, Univ. Ia. Studies Nat. Hist. 12(7): 12, 13. pl. 2, figs. 9–13, pl. 3, figs. 20–24.

Description: Internal casts of pedicle valves, moderate size for genus; suboval to semi-elliptical in ventral outline; beak pronounced, wing development at cardinal extremities; shells ventri-biconvex; greatest convexity at umbo; beak suberect; anterior commissure developes slight sulcate undulation in pedicle valve; moderate triangular delthyrium; thin median septum developed from beak anteriorly, low diverging ridges from beak to anterior portion of shell giving appearance of slight fold; brachial valve moderately convex, sharp radial ridges and concentric growth lines.

Dimensions: Average length 15.7 mm, average width 16.9 mm, median septum 5–7 mm long, surface marked by 0–3 radial ridges.

Discussion: These forms are distinguished by their relatively strong convex pedicle valves, comparatively smooth shells, and the development of a slight fold and reverse undulation of the pedicle valve at the anterior margin. The forms vary in length, 12–21 mm, the degree of undulation of the pedicle valve, and in the subelliptical to oval ventral outline.

*Gypidula* cf. *G. papyracea* differs from *G. occidentalis* (Belanski, 1928; Stainbrook, 1938) in having a lesser tendency to develop radial ornamentation, a strong anterior commissure undulation, and more evenly biconvex shell. There is a strong similarity between the Wisconsin forms and *G. comis* (Belanski, 1928; Stainbrook, 1938) in general appearance and convexity; however, that Iowa form is longer than wide, and more deeply and narrowly sulcate.

Occurrence: Belgium Member of the Lake Church Formation at Druecher and Lake Church, Wisconsin.

Catalogue specimens: Four specimens from M.P.M.—#15031, #19043.

## *Pentamerella* Hall, 1867

Type species—*Atrypa arata* Conrad, 1841
*Pentamerella* Hall, 1867, New York St. Cab. Nat. Hist., 20th Ann. Rep. p. 163; Hall and Clarke, 1894, Pal. New York. 8(2): 242, 245. pl. 71, figs. 21–29; Schuchert and Cooper, 1932, Mem. Peabody Mus. Nat. Hist. 4(1): 176. pl. 26, figs. 4, 13–17, 19, 20.
Range: Devonian

### *Pentamerella multicosta* Cleland, 1911

Pl. 2, figs. 11, 12

*Pentamerella multicosta* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 94, 95. pl. 18, fig. 18.

Description: Internal casts of moderate size shells for genus; subpentagonal to subtriangular in dorsal outline, slightly extended cardinal extremities; strongly ventri-biconvex, greatest convexity slightly posterior to midlength; anterior commissure bears squared modestly defined undulation; pedicle valve strongly convex, shell evenly rounded in lateral profile, slightly greater at umbo; beak erect to incurved, cardinal area concave; median septum extends from beak anteriorly; sulcus indistinct; brachial valve moderately convex, greatest convexity at umbo, becoming slightly flattened at cardinal extremities; low flattened fold defined from midlength to anterior margin; surface ornamented by rounded costae, costae first distinguished near midlength.

Dimensions: Average length 18.2 mm, average width 20.9 mm, average height 16.7 mm; median septum in pedicle valve 3–4 mm long; fold approximately 2 mm high, 9–10 mm wide; surface marked by 17–22 costae, 7 in fold, 5–9 on lateral slopes.

Discussion: These forms are distinguished by their strongly convex and curved pedicle valve, squared anterior commissure undulation, and development of numerous radial costae. The only significant variation noted in the three specimens available was in the number and distribution of costae.

*Pentamerella multicosta* is similar in general outline, lateral profile, and number of costae to *P. aftonensis* Imbrie, 1959; however, the great size, rectimarginate commissure, and elongate orientation of the form separates it from the Wisconsin species. *P. magna* Stainbrook, 1938, from the Cedar Valley formation of Iowa is close to *P. multicosta* in general appearance and profile; however, the large size of the shell with more numerous angular costae and the tendency to develop equal length-width dimensions distinguish these forms from the Wisconsin material. *P. dubia* Hall, 1867, (Stainbrook, 1938) also bears a strong similarity in general description to *P. multicosta*, especially figures 40–43 on plate 58 of Pal. New York, v. 4, but it can be separated by the stronger apsacline beak, and subovate dorsal outline of the Iowa form. With the discovery of better preserved Wisconsin forms, a more detailed comparison with *P. magna* and *P. dubia* may prove a closer relationship between these species.

Occurrence: The Milwaukee Formation of Estabrook Park, Milwaukee.
Catalogue specimens: One specimen from M.P.M., two from M.-D.C.—#4928.

## Suborder STROPHOMENOIDEA Maillieux, 1932
## Superfamily STROPHOMENACEA Schuchert, 1896
## Family STROPHODONTIDAE Caster, 1939
## Subfamily STROPHODONTINAE Caster, 1939
## *Pholidostrophia* Hall and Clarke, 1892

Type species—*Strophodonta nacrea* Hall, 1857
*Pholidostrophia* Hall and Clarke, 1892, Pal. New York. 8(1): 287.
*Pholidostrophia* (*Pholidostrophia*) Williams, 1950, J. Wash. Acad. Sci. 49: 280; Williams, 1953, Geol. Soc. Am. Mem. 56: 36. pl. 8, figs. 2–7; Imbrie, 1959, Am. Mus. Nat. Hist. Bull. 116: 385, 386.
Range: Devonian (Boucot, Personal communication).

**Pholidostrophia (Pholidostrophia) iowensis obscura** subsp. n.
Pl. 2, figs. 13–15

*Pholidostrophia iowensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 90. pl. 18, figs. 5–7.

Description: Moderate size shells for genus; subrectangular to semioval in dorsal outline, posterior margin straight; greatest width slightly anterior to midlength; plano-convex in lateral profile; pedicle valve moderately convex, greatest convexity at umbo; beak inconspicuous; slight evidence of denticles; very broadly triangular, bilobate muscle scar, two short linear troughs near center, scar extends almost to front of shell; brachial valve flat to slightly concave; interarea straight, narrow; two faint muscle scars flank very low median septum, low bilobed cardinal process; central area of valve irregularly marked by low rounded papillae; faint sockets along hinge line; surface smooth except for widely spaced fine concentric growth lines.

Dimensions: Average length 10.6 mm, average width 14.1 mm, height 2–4 mm; median septum in brachial valve 4 mm long; 11–12 faint tooth sockets on either side of cardinal process; 1–3 growth lines on pedicle valve; holotype #5021—length 10.6 mm, width 14 mm.

Discussion: These forms are distinctive in the Wisconsin assemblage due to their size and near lack of ornamentation. The only well defined variation noted is the degree of roundness in dorsal profile.

*Pholidostrophia iowensis obscura* is close to *P. nacrea* (Hall), 1867, in shape but differs in the degree of convexity in its pedicle valve, crescent shaped muscle scars, and distinct radial ridges anterior to the muscle scar. The Wisconsin form differs externally from *P. iowensis* (Stainbrook, 1943) in having a more quadrate outline, and in being more depressed convex; internally the brachial valve of *P. iowensis* has more distinct adductor scars, median septum and divergent ridges anterior to scars. Also, the papillae of the Iowa form are greater in number and form a more distinct pattern.

Occurrence: The Lindwurm Member of the Milwaukee Formation of Estabrook Park, Milwaukee, and the Belgium Member of the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collections of the writer and M.P.M.—#5021, #16352.

## *Protoleptostrophia* Caster, 1939

Type species—*Strophomena blainvillii* Billings, 1874

*Protoleptostrophia* Caster, 1939, Am. Paleontol. Bull. 24(83): 29, 75–78; Williams, 1953, Geol. Soc. Am. Mem. 56: 41. pl. 9, figs. 14, 15, pl. 10, figs. 1–4; Imbrie, 1959, Am. Mus. Nat. Hist. Bull. 116: 387.

*Leptostrophia* Allan, 1947, J. Paleontol. 21: 438, 439.

Range: L.—M. Devonian

**Protoleptostrophia serrata** sp. n.
Pl. 2, figs. 16–19

*Strophеondonta perplana* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 89. pl. 18, figs. 1–4.

Description: Moderate size shells for genus; semielliptical to subquadrate in dorsal outline, posterior margin nearly straight, beak indistinct, cardinal extremities develop slight wings; greatest width along hinge line; plano to concavo-convex in lateral profile, greatest height near midlength of shell; pedicle valve slightly convex, greatest convexity at umbo; large triangular muscle field at center of shell, bounded by straight ridges, two major lobes divided by slightly curving median septum, each lobe secondarily divided by 3–4 straight to slightly curved ridges, surface lateral to muscle scar heavily papillous with no significant pattern; fine pallial markings near anterior and lateral margins; brachial valve flat to slightly concave, straight hinge line with moderate sockets; moderate bilobed cardinal process, very fine longitudinal striations on bottoms of processes: moderate bilobate suboval muscle scar divided by median septum anterior to cardinal process, fine costellae radiate from muscle

scars which bear fine papillae especially near center of shell, moderate papillae flank scars without orientation; surface ornamented by moderate, freely intercalating costellae, crossed by numerous fine concentric growth lines which correspond to small hoods along ribs giving costellae serrated appearance; secondary growth lines develop between major fila, interruption of growth caused occasional concentric striae; every fourth to fifth rib appears slightly stronger.

Dimensions: Average length 15.2 mm, average width 20.2 mm; muscle field angle of pedicle valve 60°; radial costellae in brachial valve muscle scar averages 1.4 per mm near anterior margin; 3.5 radial costellae per mm; 18–20 tooth sockets on either side of cardinal process; holotype #16297—length 21 mm, width 28 mm.

Discussion: *Protoleptostrophia serrata* is separated easily from the Wisconsin assemblage by its flat shell and distinctive surface ornament. Very little variation was noted except in the size of the specimens. The length varied from 5–24 mm and width from 8–30 mm. In addition, the wing profile varied from square to acutely pointed extensions 1–2 mm in length.

*Protoleptostrophia lirella* Imbrie, 1959, is similar to *P. serrata* in general outline, but has a wider pedicle muscle field, a strongly convex pseudodeltidium and more evenly defined costellae with less distinct rib projections. The Iowa form *P. occidentalis* (Stainbrook), 1943, similar in outline, strength of costellae and rib projections, pedicle muscle field deviation, and in possessing a flat pseudodeltidium; however, *P. serrata* has more subequal costellae, a less robust pedicle valve, and a more elongate pedicle muscle field. *P. blainvillii* (Billings), 1874, bears an amazing resemblance to the Wisconsin form in shape, general pedicle muscle field appearance, and practically identical brachial interior. However, the pedicle muscle scar is broader and the costellae are described as "fine, rounded or subangular." It seems possible that the Wisconsin specimens and also *P. occidentalis* are closely related to that Canadian form.

Occurrence: Lindwurm, and Berthlet Members of the Milwaukee Formation at North Avenue Intake Tunnel and Estabrook Park, Milwaukee.

Catalogue specimens: Collections of the writer, M.-D.C. and M.P.M.—#16297, #321, #C541.

## *Strophodonta* Hall, 1850

Type species—*Leptaena demissa* Conrad, 1842

*Strophodonta* Hall, 1850, Am. Assoc. Adv. Sci. Proc. 2: 348, 349; Hall, 1858, Iowa Geol. Surv. Rep. 1(2): 491; Hall, 1867, Pal. New York. 4: 78; Imbrie, 1959, Am. Mus. Nat. Hist. Bull. 116: 374–376.

*Strophеodonta* Hall, 1852, Pal. New York. 2: 63; Hall and Clarke, 1892, Pal. New York. 8(1): 284–289; Williams, 1953, Geol. Soc. Am. Mem. 56: 34, 35. pl. 7, figs. 1–13.

*Strophodonta* spelling after Imbrie (1959).

Range: Devonian

## *Strophodonta* cf. *S. costata* Owen, 1852

Pl. 2, fig. 20

*Strophеodonta* cf. *S. costata* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 87. pl. 14, figs. 5, 6.

Description: Shells small for genus; semielliptical to subrounded in ventral outline, posterior margin straight to slightly extended cardinal extremities; concavo-convex; pedicle valve very slightly convex, greatest convexity at umbo; beak small, may extend slightly beyond hinge line; interior of flat or slightly convave brachial valve has small cardinal process, numerous papillae over entire surface, and inward sloping denticles; surface marked by three generations of angular intercalated costae, costae become obsolete on wings.

Dimensions: Average length 7.1 mm, average width 11.1 mm; 8–9 primary costae begin at beak, 2–3 per mm at anterior margin.

Discussion: These shells are quite distinctive due to their small size and nearly flat appearance. There is a slight variation in the extension of the cardinal extremities. Also, the pedicle valves vary from nearly flat to slightly convex.

The Wisconsin forms are similar to *Strophodonta costata* (Stainbrook, 1938) and *S. costata*

var. *independensis* Stainbrook, 1938, but differ in having subangular costae, lesser length to width ratio, and a much less convex shell.

Occurrence: Lindwurm Member of the Milwaukee Formation, Estabrook Park, Milwaukee, and the Ozaukee Member of the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collection of the writer, M.P.M. and Robert Reyer—#A-32.

## *Strophodonta halli* Cleland, 1911
## Pl. 2, figs. 21–25

*Strophodonta demissa* Hall, 1858, Iowa Geol. Surv. Rep. 1(2): 495. pl. 3, figs. 5a, b, c, d.
*Strophodonta demissa* Whitfield, 1882, Geol. Wisconsin. 4: 327. pl. 25, fig. 18.
*Stropheodonta halli* Cleland, 1911, Wis. Geol. Nat. Hist. Surv. Bull. 21: 87. pl. 14, figs. 7–10.

Description: Moderate to large shells for genus; semielliptical to subrectangular in ventral profile, posterior margin very slightly convex, posterior and lateral margins meet at 80–90° angle forming very slightly extended cardinal extremities, lateral margins straight, anterior lateral and anterior margin nearly straight to regularly rounded; greatest width at or equal to hinge line; concavo-convex in lateral profile; cardinal area straight; pedicle muscle scar strongly flabellate, reaching to midlength of valve subdivided by poorly defined irregular ridges, major lobes divided by split elliptical median septum, numerous unoriented papillae surround muscle scar becoming finer toward margins, anterior and lateral margins bear numerous pallial markings; brachial valve concave, straight cardinal area, inward oriented denticles along entire hinge line, moderate bilobed cardinal process; adductor muscle scars subelliptical, separated by two low median septa; anterior and lateral areas of scar bear numerous strong papillae which become finer toward margins; surface marked by subangular to rounded irregular intercalating costae, concentric growth lines appear only near margins.

Dimensions: Average length 28.6 mm, average width 39.4 mm, average height 10.2 mm; 2–3 costae per mm near anterior margin, median septum in pedicle valve 10 mm long, 5 mm wide.

Discussion: *Strophodonta halli* is a very common form in the Lindwurm and Berthlet members of the Milwaukee Formation, and can be distinguished by its large size, profile, and surface ornament; however, considerable variation does exist. The external variations noted, such as the development of slightly extended wings, a subrectangular to elliptical ventral outline, slight to moderately strong convexity, and shell height are quite prominent, yet a definite overall similarity and gradation of characteristics exists when examining large numbers of individuals. Imbrie (1959) discussed the problem of ecological population variation and demonstrated the necessity to examine group characteristics in strophodontid and other forms. The Traverse and Cedar Valley strophodontid faunas are equally as distinctive as the Wisconsin forms and each seems to have developed a wide specific or subspecific variation similar to that proposed for *S. extenuata* (Imbrie, 1959). All the Wisconsin material is placed under *S. halli* at this time due to the significant gradation noted except for *S.* sp. A, which is described from single specimen and shows a similarity to *S. halli* but due to its distinctive ornament is not given a specfiic attachment. *S. halli* differs from the Cedar Valley form *S. cedarensis* Stainbrook, 1938, *S. littletonensis* Stainbrook, 1938, and *S. halli* (Stainbrook, 1938) in having heavier, more rounded costae which are wider than the intervening striae. *S. halli* differs from the Traverse form *S. pentagonia* Imbrie 1959, and *S. tenuicosta* Imbrie, 1959, in having rounded to subangular, more numerous costae, a generally larger shell, and a more semielliptical outline.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.-D.C., the writer—#A-36, and M.P.M.—#310, #10987.

## *Strophodonta* sp. A
## Pl. 3, figs. 1–3

Description: Ventral valve of moderate shell for genus; semielliptical in ventral outline, straight hinge line with slight beak; moderately convex, greatest convexity at umbo; greatest height slightly anterior to midlength; surface marked by broad, subangular to sub-

rounded costae with intercalations and bifurcations beginning at umbo; on anterior portion of shell costae reduce to finer, more angular form, with additional intercalactions which double number of costae within distance of 2 mm forming distinct boundary between the two sets of radial ornamentation (pl. 3, fig. 1).

Dimensions: Length 29 mm, width approximately 36 mm, height 10 mm; 2 costae per mm at umbo, 3–4 per mm at anterior margin.

Discussion: This form is described from a single specimen but is distinctive because of its unusual surface ornament. This distinction seems to warrant the establishment of a new species or subspecies, however, because of the lack of material at this time it is not felt a new name should be applied.

There is a general similarity in appearance to *Strophodonta halli* which may indicate a specific relationship between these forms, however, no gradation between ornament types was observed. The Wisconsin form is comparable to *S. fissicosta* Imbrie, 1959, in the manner of ornamentation; however, the thin angular costae and small size of that form separates it from the Wisconsin specimen. The Cedar Valley form *S. cedarensis* Stainbrook, 1938, is similar in shape, convexity of pedicle valve, and pronounced intercalation of costae. However, the same distinct difference as noted in the discussion of *S. halli*, the rounded to subangular more numerous costae, and narrower striae separate the Wisconsin and Iowa forms.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimen: Collection of the writer—#A-39.

### *Strophodonta* sp. B
Pl. 3, fig. 4

Description: Shell small for genus; semielliptical in ventral outline, straight hinge line with small beak; greatest width along hinge line; moderately convex; greatest height at mid-length, slightly concave at cardinal extremities; interior of pedicle valve marked by divided strong median septum separating large indistinct muscle scars, divided ridges of septum join anteriorly; hinge line bears denticles along entire length; surface marked by numerous sub-angular freely bifurcating costellae, few concentric growth lines near margin.

Dimensions: Average length 13.4 mm, average width 18.8 mm; median septa 5–6 mm long; surface marked by approximately 40 costellae.

Discussion: This group is represented by only a few poorly preserved specimens, but is distinct because of the small size and weakly defined internal characteristics. The only variation noted was the tendency to develop slightly extended wings. The Wisconsin specimens are similar to *Strophodonta cicatricossa* Belanski, 1929 in outline, lack of a well defined pedicle muscle scar, and convexity. However, the Iowa form has a more distinct marginal thickening, a longer median septum, and a more strongly curving ventral outline. There also is a similarity to *S. parva* (Stainbrook, 1938) in general size and shape, but due to a lack of well preserved material, the comparison with this Iowa form was not considered significant.

Cleland's figure 11 on plate 14 of *Strophodonta halli* var. *musculosa* appears very close to *S.* sp. B. However, figure 12 on the same plate, which shows the pedicle valve of this form, displays distinctly different interior development than *S.* sp. B. It seems possible that figure 12 may be a small specimen of *S. halli* and figure 11 a distinctly convex specimen of *S.* sp. B.

Occurrence: Ozaukee Member of the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collection of M.P.M.—#14971.

## Superfamily ORTHOTETACEA Williams, 1953
## Family SCHUCHERTELLIDAE Stehli, 1954
## Subfamily SCHUCHERTELLINAE Williams, 1953
### *Schuchertella* Girty, 1904

Type species—*Streptorhynchus lens* White, 1862

*Schuchertella* Girty, 1904, U. S. Nat. Mus. Proc. 27: 734; Weller, 1914, Ill. Geol. Surv. Mon. 1: 53, 54; Dunbar and Condra, 1932, Neb. Geol. Surv. Bull., Ser. II. 5: 70–73; Stainbrook, 1943, J. Paleontol. 17: 41, 42; Stehli, 1954, Am. Mus. Nat. Hist. Bull. 105: 298.

Range: L. Devonian—Permian

## *Schuchertella artostriata* (Hall), 1843
## Pl. 3, figs. 5, 6

*Strophomena arctostriata* Hall, 1843, Geol. New York, Rep. Fourth Dist., p. 266. fig. 3.
*Orthisina arctostriata* Hall, 1860, New York St. Cab. Nat. Hist., 13th Ann. Rep., p. 80, 81. figs. 1, 2.
*Streptorhynchus chemungensis arctostriata* Hall, 1867, Pal. New York. 4: 71. pl. 9, figs. 1–12.
*Hemipronites chemungensis arctostriata* Meek, 1877, U. S. Geol. Explor. 40th Parallel (King). 4: 35. pl. 3, fig. 2.
*Streptorhynchus arctostriata* Walcott, 1884, U. S. Geol. Surv. Mon. 8: 177. pl. 13, fig. 7.
*Orthothetes chemungensis arctostriata* Hall and Clarke, 1892, Pal. New York. 8(1). pl. 10, fig. 8.
*Schuchertella arctostriata* Grabau and Shimer, 1909, N. Am. Index Fossils, I. p. 229, 230. fig. 280a, b.
*Schuchertella chemungensis arctostriata* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 91. pl. 16, fig. 15.
*Schuchertella arctostriata* Branson, 1922, Mo. Bur. Geol. and Mines. 2nd ser., 17: 83, 84. pl. 15, figs. 8, 9, 12; pl. 24, figs. 18–23.

Description: Shells small to moderate for genus; subrectangular to subcircular in dorsal outline, posterior margin straight, slightly extended cardinal extremities; ventri-biconvex, greatest convexity at umbo of both valves; greatest width posterior to midlength, slightly wider than hinge line; pedicle valve strongly convex; greatest height at extended sharp beak; interarea deep, broadly triangular with long, triangular raised deltidium marked by median trough, interarea junction perpendicular to slightly acute to hinge line; brachial valve moderately convex, greatest height at umbo, becomes slightly concave at wings; beak small, extends slightly beyond hinge line; surface ornamented by subangular to rounded costellae, ribs bifurcate and intercalate freely; concentric growth lines numerous, tend to become slightly lamellose near margins.

Dimensions: Average length 10.8 mm, average width 14.5 mm, height of brachial valve 5.5 mm; 12–15 primary costellae begin at beak, 3–4 costellae per mm at anterior margin.

Discussion: This species is very distinctive due to its broad perpendicular interarea,

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EXPLANATION OF PLATE 3

FIGS. 1–3. *Strophodonta* sp. A; 1–3, pedicle, lateral, and posterior views, Lindwurm Member, Milwaukee Formation, locality 3, writer's collection #A–39, ×0.9; p. 262.
4. *Strophodonta* sp. B; interior pedicle view, Ozaukee Member, Lake Church Formation, locality 1, M.P.M. #14971, ×1.3 p. 263.
5–6. *Schuchertella artostriata* (Hall), 1843; 5, pedicle view, Lindwurm Member, Milwaukee Formation, locality 1, M.P.M. #16371, ×2.3; 6, brachial view, from same locality, M.P.M. #16366, ×1.8; p. 264.
7–9. *Spinulicosta spinulicosta* (Hall), 1867; 7–9, pedicle, lateral, and posterior views, Lake Church Formation, locality 1, M.P.M. #15088, ×1.8; p. 266.
10–12. *Spinulicosta spinulicosta* subsp. A; 10–12 pedicle, lateral and anterior views, Lake Church Formation, locality 1, M.P.M. #23088, ×1.3; p. 267.
13–15. *Chonetes schucherti* Cleland, 1911; 13, brachial view, Lindwurm Member, Milwaukee Formation, locality 1, M.P.M. #16393, ×2.7; 14, interior brachial view, same locality, number, and magnification; 15, pedicle view of more robust, rectangular form, same locality, number, and magnification; p. 267.
16. *Longispina?* cf. *L. vincinus* (Castelnau), 1843; interior pedicle view, Lake Church Formation, locality 1, M.P.M. #15070, ×1.8; p. 268.
17–20. *Cupularostrum depressa* (Kindle), 1901; 17, anterior view, Lindwurm Member, Mialwaukee Formation, locality 3, M.P.M. #378, #14825, #16450, ×2.7; 18–20, anterior, lateral, and brachial views, same locality, numbers, and magnification; p. 269.
21–23. *Cupularostrum* cf. *C. prolifica* (Hall), 1867; 21–23, brachial, lateral, and anterior views, Milwaukee Formation, locality 1, M.–D.C. #5796, ×2.7; p. 269.
24–26. *Cupularostrum scitulus* (Cleland), 1911; 24–26, brachial, anterior, and lateral views, Milwaukee Formation, locality 1, M.–D.C. #5162, ×1.3; p. 270.
27–29. *Leiorhynchus greeni* Cleland, 1911; 27, lateral view, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #387, ×1.3; 28, 29, anterior and brachial views, same locality, M.–D.C. #5116, ×1.3; p. 271.

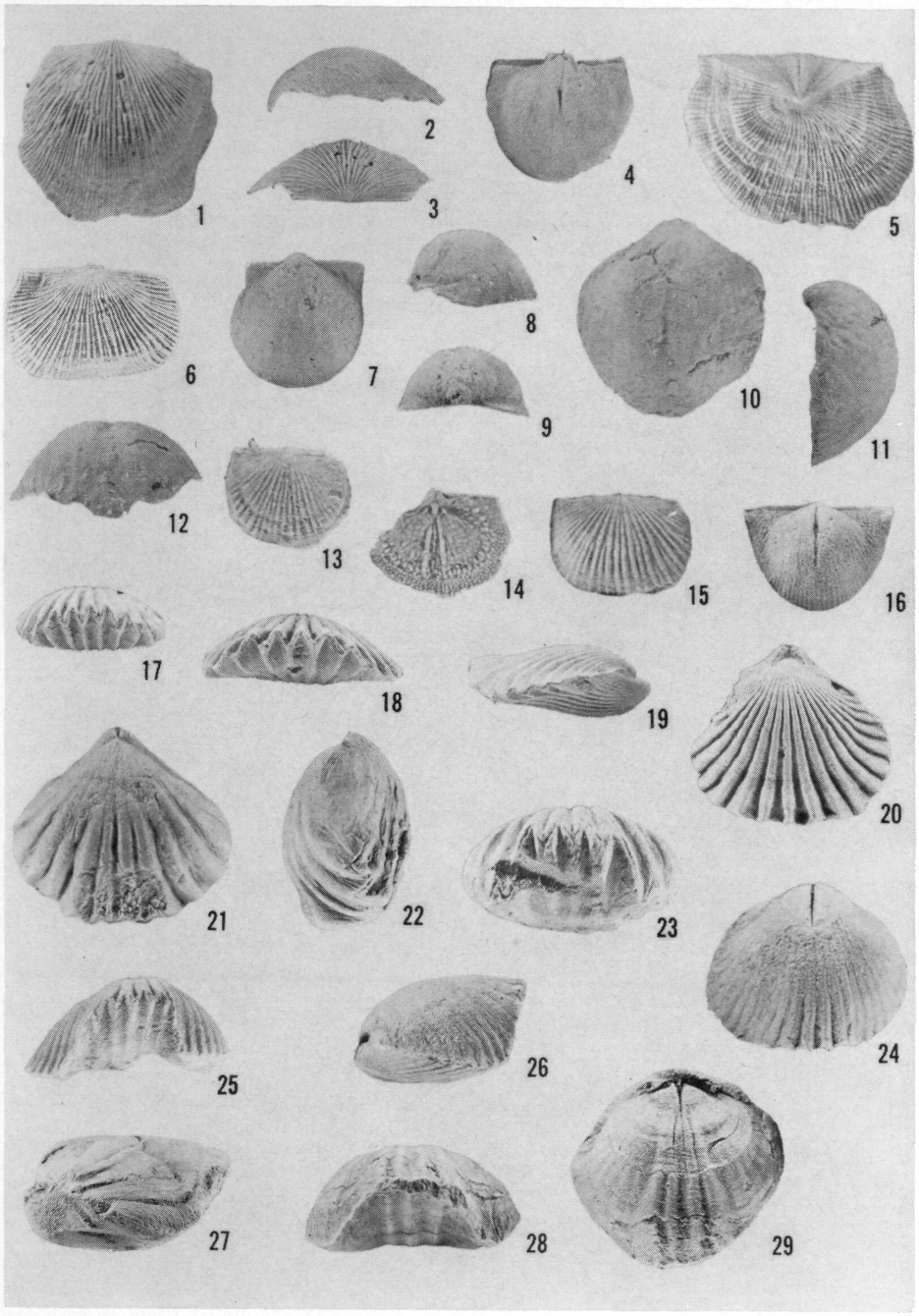


PLATE 3

distinct intercalating ornament, and sharp pedicle beak. These shells are often badly crushed, eliminating authentic variation. However, the shells vary slightly in dorsal outline from nearly circular to distinctly subrectangular and the angle of the interarea ranges from acute to perpendicular.

The Wisconsin specimens show some similarity to *Schuchertella anomala* (Imbrie, 1959) and *S. lirella* (Imbrie, 1959) of the Traverse Group. However, both these species are much larger and more irregular in outline than is *S. arctostriata*. *S. lirella* also shows a trend toward gibbosity which is not evident in the Wisconsin forms. *S. prava* (Stainbrook, 1945) from the Upper Devonian of Iowa has the same general appearance as the Wisconsin forms, but has finer and more numerous costellae. *S. iowensis* Stainbrook, 1943, differs from the Wisconsin species in being considerably larger, having numerous costellae, a less elliptical outline, and no tendency to develop wings. The shells show a marked resemblance to *S. arctostriata* (Branson, 1922) from the Missouri section.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collection of the writer and M.P.M.—#16371, #16366.

## Suborder PRODUCTOIDEA Mailleux, 1940
## Superfamily PRODUCTACEA Waagen, 1883
## Family PRODUCTIDAE Gray, 1840
## Subfamily PRODUCTELLINAE Schuchert and LeVene, 1929
## *Spinulicosta* Nalivkin, 1937

Type species—*Producta spinulicosta* Hall, 1857

*Spinulicosta* Nalivkin, 1937, Cent. Geol. Prosp. Inst. U.S.S.R. Trans. 99: 49, 140; Muir-Wood and Cooper, 1960, Geol. Soc. Am. Mem. 81: 153–155. pl. 32, figs. 1–4, pl. 33, figs. 1–17.

Range: M.—U. Devonian

### *Spinulicosta spinulicosta* (Hall), 1867
### Pl. 3, figs. 7–9

*Producta spinulicosta* Hall, 1867, Pal. New York. 4: 160. pl. 23, figs. 25–34.

*Producta spinulicosta* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 93. pl. 18, figs. 14–16.

Description: Internal pedicle valve casts of small shells for genus; subcircular in ventral outline, hinge line straight; greatest convexity at umbo, greatest height near center of shell, regularly rounded in lateral and posterior profile; nearly flat distinct wings, greatest width along hinge line; surface ornamented by elongate spine bases along indistinct radial patterns beginning at beak; faint concentric rugae evident on umbo and lateral slopes.

Dimensions: Average length 10.8 mm, average width 11 mm, height 5–6 mm; concentric rugae extend approximately 4 mm from beak to anterior margin.

Discussion: *Spinulicosta spinulicosta* from the Wisconsin section is distinguished by its small equidimensional shape, smoothly rounded lateral profiles, and distinct wings. Not enough material was available to make a significant study of variation.

The Wisconsin specimens appear slightly more elongate, but closely resemble Hall's description of this species as described in Pal. New York, v. 4, pl. 23, figs. 25–34. *Spinulicosta mutacosta* Imbrie, 1959, is similar in size, outline, and convexity. However, the Michigan species can be separated from *S. spinulicosta* by its greater height and well defined incurved beak. The poor preservation of the Wisconsin specimens warrants a comparison to *Helaspis luma crista* Imbrie, 1959. This Michigan form has a similar convexity and transverse outline to *S. spinulicosta*, but the lack of concentric rugae on the posterior slopes, and fewer spine bases seem to separate it from the Wisconsin material.

Occurrence: Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collection of M.P.M.—#15088.

### *Spinulicosta spinulicosta* subsp. A

Pl. 3, figs. 10–12

Description: Internal pedical valve casts of moderate shells for genus; suboval to subround in ventral outline, concave posterior margin due to strongly extended beak, very slight wings; greatest convexity at umbo, greatest height slightly posterior to midlength; surface ornamented by faint radial costae which show no apparent relationship to numerous elongate spine bases; concentric rugae prominent from beak on posterior portion of shell, additional secondary rugae evident more anteriorly; slight sulcus present from front portion of umbo to anterior margin, 1–2 mm wide near front of shell.

Dimensions: Average length 16.8 mm, average width 19.9 mm, height 8–9 mm.

Discussion: This form is distinguished by its large size, sulcate pedicle valve, and strong surface ornament. *Spinulicosta spinulicosta* of the Wisconsin section can be separated from this form by its smaller size, less strongly incurved beak, and less distinct surface ornament. *S. arctirostrata* (Hall), 1867, is very close to the Wisconsin species in general outline, wing development, and depression in the pedicle valve. However, this Upper Devonian form has significantly stronger concentric and radial ornament.

Occurrence: Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Three specimens from M.P.M.—#23088.

## Suborder CHONETOIDEA Muir-Wood, 1955

## Superfamily CHONETACEA Shrock and Twenhofel, 1953

## Family CHONETIDAE Bronn, 1862

### *Chonestes* Fischer de Waldheim, 1830

Type species—*Terebratulites sarcinulatus* Schlothein, 1820

*Chonetes* Fischer de Waldheim, 1830, Oryctographie du Gouvernement de Moscow, 1st edit. p. 134. pl. 26, figs. 8, 9; De Konick, 1844, Description des animaux fossils que se trouvent dans le terrain Carbonifere de Belgique. p. 206–213; Hall and Clarke, 1894, Pal. New York. 8(2): 303–309; Imbrie, 1959, Am. Mus. Nat. Hist. Bull. 116: 392–395.

Range: M. Silurian—Permian

### *Chonetes schucherti* Cleland, 1911

Pl. 3, figs. 13–15

*Chonetes schucherti* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 91, 92. pl. 18, figs. 11–13.

Description: Shells small for genus; semicircular to subrectangular in ventral outline, slightly extended beak; greatest convexity and height anterior to midlength; concavo-convex to plano-convex; greatest width slightly wider than hinge line; pedicle valve slightly convex; hinge line bears laterally projecting spine bases on each side of beak; brachial valve flat to slightly concave; hinge line straight; interior shows moderate cardinal process with median septum bifurcating just anterior to process, then becoming trifid with lateral ridges dominant, reaching nearly to front of shell; interior surface covered by papillae, strongest papillae form elliptical band which closely parallels margin; muscle scar near cardinal process indistinct; external surface marked by numerous subrounded costellae which intercalate freely, very fine concetric growth lines over entire shell become slightly crowded near margins.

Dimensions: Average length 7.0 mm, average width 5.2 mm, average height 1.3 mm; 2–3 spine bases on each side of beak; 30–40 costellae per shell.

Discussion: These shells are very distinctive in the Wisconsin section due to their small size and flat profile. There seems to be some variation in ventral outline from regularly rounded to subrectangular lateral and anterior margins. The more rectangular specimens appear slightly more convex. Some gradation between the two variations was noted.

The Wisconsin specimens most closely resemble *Chonetes scitulus* (Hall), 1867, in general shape, size, and the presence of a trified median septum with dominant lateral ridges. How-

ever, *C. schucherti* has fewer costellae (60–40) and a more variable development of papillae on the interior of the brachial valve. There is also a resemblance to *C. brandonensis* Stainbrook, 1945, but this form also has finer and more numerous costellae and is slightly more inflated.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of the writer, M.-D.C. and M.P.M.—#16393.

### *Longispina* Cooper, 1942

Type species—*Chonetes emmetensis* Winchell, 1866

*Longispina* Cooper, 1942, J. Wash. Acad. Sci. 32(8): 230; Imbrie, 1959, Am. Mus. Nat. Hist. Bull. 116: 397.

Range: L.—M. Devonian

### *Longispina?* cf. *L. vicinus* (de Castelnau), 1843

Pl. 3, fig. 16

*Leptaena vicina de* Castelnau, 1843, Systême sil. l'Amerique septemtrionale. p. 39. pl. 14, fig. 9.

*Chonetes vicina* De Koninck, 1847, Recher. Animaux Foss. 1: 203.

*Chonetes deflecta* Hall, 1867, Pal. New York. 4: 126. pl. 21, figs. 7, 8.

*Chonetes vicinus* Schuchert, 1897, U. S. Geol. Surv. Bull. 87: 180.

*Chonetes vicinus?* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 92. pl. 18, figs. 8–10.

Descriptions: Internal casts of moderate size shells for genus; semielliptical to subcircular in ventral outline, posterior margin straight extending to slightly mucronate cardinal extremities; shells gibbose, greatest convexity at umbo, greatest height at midlength, becomes concave and flattened at cardinal extremities; greatest width along hinge line; small beak slightly overhangs hinge line; long well developed median septum extends from beak past midlength; surface marked by subangular freely bifurcating and intercalating radial costellae; very slight spine bases noted along hinge line.

Dimensions: Average length 8.4 mm, average width 10.8 mm, average height 3.9 mm; surface marked by 30–40 costellae; median septum 0.7 mm wide, 5–6 mm long.

Discussion: These forms are distinguished in the Wisconsin section by their long single median septum, numerous costellae, and distinctly gibbose shells. *Longispina?* cf. *L. vicinus* has a similar appearance to *Strophodonta* sp. B of the Lake Church Formation, but shows no denticles along the hinge line and has less distinct internal pedicle characteristics. No significant variation was noted among the specimens available. *L.?* cf. *L. vicinus* is similar in shape and convexity to *Chonetes lineata* Hall, 1867; however, the Wisconsin form has fewer costellae and a more semielliptical outline. There is a similarity between the Wisconsin species and *C. sibleyensis* Bassett, 1935, but this Michigan form is larger and much more costellate. *C. scitulites* Cooper, 1945, can be separated from the Wisconsin material because of its more costellate surface, lesser gibbosity, and the position of greatest width at the midlength of the shell rather than at the hinge line.

Occurrence: Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collections of M.P.M.—#15070.

## Suborder RHYNCHONELLOIDEA Moore, 1952

## Superfamily RHYNCHONELLACEA Schuchert, 1896

## Family CAMAROTOECHIIDAE Schuchert and LeVene, 1929

### *Cupularostrum* Sartenaer, 1961

Type species—*Cupularostrum recticostatum* Sartenaer, 1961

*Camarotoechia* Hall and Clarke, 1894, Pal. New York. 8(2): 189.

*Cupularostrum* Sartenaer, 1961, Inst. Royal des Sci. Nat. de Belgique Bull. 37(25): 1–15. 2 pl.

Range: Devonian

## *Cupularostrum depressa* (Kindle), 1901
Pl. 3, figs. 17–20

*Rhynchonella* (*Stenocisma*) *contracta* var. *saxatilis* Hall, 1867 Pal. New York. 4: 417. pl. 54a, figs. 50, 51.
*Rhynchonella depressa* Kindle, 1901, Ind. Dept. Geol. and Nat. Hist. 25th Ann. Rept. p. 589. pl. 7, figs. 5, 5a, 5b.
*Camarotoechia contracta* var. *saxatilis* Cleland, 1911, Wis. Geol. and Nat. Hist. Survey Bull. 21: 70. pl. 13, figs. 3–5.
*Camarotoechia eximia* Prosser, 1913, Md. Geol. Survey, Middle and Upper Devonian. p. 579. pl. 54, figs. 1–4.

Description: Shell small for genus; valves nearly equally convex, greatest convexity at umbo, appear unevenly convex in lateral profile due to flaring at extremities; subtriangular in outline, posterior lateral margin slightly concave as beak of pedicle valve extends beyond brachial valve; broad undulation of anterior commissure forms indistinct fold; pedicle valve has sharp suberect beak which may project above hinge line; brachial valve evenly convex except for gently upturned flare slightly posterior to anterior margin; surface marked by subangular plications which begin at beak curving slightly and broadening toward lateral margins with no increase in number; very slight evidence of concentric growth lines.

Dimensions: Average length 7.9 mm, average width 9.2 mm, average height 3.7 mm; beak angle averages 101°; 18–27 plications, 5–6 in fold, height of bounding plications averages 1.3 mm, fold width averages 4.3 mm.

Discussion: These specimens can be characterized by their moderately thin shells, sharp thin extremities, and low poorly defined folds. The greatest variation noted in these shells is in the degree of marginal flattening; this variation can be seen on plate 3, figures 17 and 18. Other minor variations such as a subtriangular to subelliptical dorsal profile, the occasional presence of very subdued growth lines, and a fold expressed only by stronger central plications are also evident. In general description these shells are quite similar to *Cupularostrum formosensis* (Fagerstrom), 1961, and *C. ambigua* (Fagerstrom), 1961, species recently described from the Formosa Reef Limestone of southern Ontario. However, *C. formosensis* appears to have a much more distinct fold, a more evenly convex lateral profile, and the plications seem less inclined to broaden toward the margins. *C. ambigua* closely resembles the Wisconsin specimens in overall shape and commissure configuration; however, the presence of prominent growth lines and low, rounded irregularly spaced plications clearly distinguishes it from these forms. *C. depressa* is also very close to *C. cedarensis* (Stainbrook), 1942, but differs in being less convex and having a much more poorly defined fold. These shells closely resemble *C. eximia* as pictured by Hall, Pal. New York, v. 4, pl. 55, fig. 1. Prosser apparently used this figure as the basis for identifying his specimens in the Maryland Geol. Survey report on the Middle and Upper Devonian as *C. eximia*; however, there seems to be little other basis for comparison in the description of the Maryland and New York specimens. Whether or not Hall found a continuing progression of forms from his figure 1 to figures 2–8 is unclear. Therefore since Prosser's description of his specimens is much closer to *C. depressa* of Kindle (1901) and larger specimens of this species from the Wisconsin section retaining their flattened appearance and low poorly defined fold have been found, it seems only reasonable to refer the Wisconsin and Maryland forms to *C. depressa*.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Unnumbered specimens from M.P.M. in box labelled—#378, #14825, #16450.

## *Cupularostrum* cf. *C. prolifica* (Hall), 1867
Pl. 3, figs. 21–23

*Rhynchonella* (*Stenocisma*) *prolifica* Hall, 1867, Pal. New York. 4: 343. pl. 54a, figs. 1–10.
*Camarotoechia prolifica* Hall and Clarke, 1894, Pal. New York. 8(2): 192. pl. 57, figs. 42, 43.
*Camarotoechia prolifica* Branson, 1923, Mo. Bur. Geol. and Mines. 2nd ser., 17: 143. pl. 34, figs. 15–17.

Description: Moderate size shell for genus; nearly equally biconvex in lateral profile, brachial valve slightly dominant; subtriangular in dorsal outline; greatest convexity near mid-

length of shell; extremities rounded; pedicle valve moderately convex, greatest convexity at umbo and moderate sulcus; beak moderately sharp, suberect; brachial valve moderately convex, greatest convexity at umbo; fold becomes distinct at midlength of shell, slopes slightly toward anterior margin; surface marked by subangular to round plications.

Dimensions: Length 10.0 mm, width 11.0 mm, height 6.5 mm; beak extends beyond brachial valve 0.7 mm; beak angle 98°; fold width 4.3 mm, height of lateral fold plication 4.2 mm; 14 plications on shell, 4 in fold.

Discussion: This form is described from a single specimen, which is quite distinctive from the rest of the Wisconsin assemblage because of its strong, few subangular plications and greater height. In general shape, size, and number of plications, the Wisconsin form is similar to *Cupularostrum tethys* (Fagerstrom, 1961). However, the abrupt curvature of the lateral profile and the very distinct fold seem to separate this form from *C. prolifica.*

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimen: One specimen from M.–D.C.—#5796.

### *Cupularostrum scitulus* (Cleland), 1911
Pl. 3, figs. 24–26

*Camarotoechia scitulus* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 71. pl. 12, figs. 6, 7.

Description: Internal casts of large shells; strongly dorsi-biconvex; suboval to subtriangular in dorsal outline; deep sulcus in pedicle valve raises commissure near top of brachial shell; lateral margins slightly flattened; pedicle valve slightly convex; brachial valve strongly convex, greatest convexity at umbo, regularly curving from umbo to front of shell; greatest height slightly posterior to anterior margin, remains nearly horizontal along crest of fold; surface marked by rounded to subangular plications, single plication on slopes of fold.

Dimensions: Average length 16.4 mm, average width 19.5 mm, average height 11.9 mm; beak angle averages 110°; height of lateral fold plications 6 mm, average fold width 8.3 mm; median septum extends 4–5 mm anteriorly; 25–30 plications on shell, 5–6 in fold.

Discussion: These forms are distinctive in the Wisconsin section due to their large size and convexity. The forms show variation in the number of plications and in the degree of their subtriangular profile; however, the lack of well preserved material at present does not allow a significant discussion of variation.

*Cupularostrum sappho* (Hall) shows a resemblance to *C. scitulus* in general outline, but the strength and angularity of the plications and the strongly rounded brachial valve and fold near the anterior margin distinguishes *C. sappho* from the Wisconsin form. *C. orbicularis* is comparable to *C. scitulus* in its dorsal outline and general dimensions; however, the convexity of the pedicle valve and the distinctly curved lateral profile of the brachial valve near the front of the shell separate this species from *C. scitulus.* Branson established a new species, *C. gregeri* (Branson), 1923, on forms previously described by Greger (1920) as *C. scitulus.* Branson felt that the quadrangular outline and fewer plications warranted the separation of Missouri and Wisconsin forms. A distinct similarity in general outline and size exists between *C. scitulus* and *C. congregata* var. *parkheadensis* (Clarke and Swartz), 1913, from the Upper Devonian of Maryland. The Wisconsin form can be separated by its more compressed pedicle valve and slightly finer and more numerous plications. The future discovery of better preserved specimens from the Wisconsin section might warrant the re-examination of the type specimens of *C. gregeri* and *C. congregata* var. *parkheadensis.*

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Four specimens from M.–D.C.—#5162.

### *Leiorhynchus* Hall, 1860

Type species—*Orthis quadracostata* Vanuxem, 1842

*Leiorhynchus* Hall, 1860, New York St. Cab. Nat. History, 13th Ann. Rep. p. 75; Schuchert, 1897, U. S. Geol. Surv. Bull. 87: 236; Sartenaer, 1961, J. Paleontol. 35: 963–976.

*Lirohynchus* Hall and Clarke, 1894, Pal. New York. 8(2). pl. 59, figs. 21, 22.

*Nudirostra* Cooper and Muir-Wood, 1951, Wash. Acad. Sci. 41: 195.

Range: M. Devonian—Pennsylvanian

### *Leiorhynchus greeni* Cleland, 1911
Pl. 3, figs. 27–29

*Leiorhynchus greeni* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 21. pl. 13, figs. 1, 2.

Description: Internal casts of moderate size shells for genus; subcircular to subquadrate in dorsal outline, anterior margin flattened; equally biconvex in lateral profile, greatest convexity at umbo of both valves, crest of brachial and pedicle valves appear nearly parallel; anterior commissure forms broad moderately strong undulation; pedicle valve moderately convex; subelliptical to tear shaped symmetrical muscle scar at umbo; beak extends slightly beyond brachial valve; brachial valve moderately convex, slopes slightly along crest of fold to anterior margin; moderate fold; strong median septum; surface marking most prominent along fold area, plications round to subangular; lateral surface in some specimens shows no radial markings; prominent concentric rugae noted on most shells with broad flat interspaces.

Dimensions: Average length 20.4 mm, average width 20.6 mm, average height 12.1 mm, pedicle muscle scar averages 16.1 mm long, 3.2 mm wide; 6–16 plications on shell, 4–6 on fold, 0–6 on lateral slopes; average fold height 7.2 mm, average fold width 7.4 mm; median septum becomes trifid on average 2–4 mm from beak; concentric rugae 10–15 mm apart, first ridge developes 5–6 mm from beak.

Discussion: These forms are easily distinguished by their prominent fold-sulcus plications and relatively bare lateral slopes. As is characteristic for this genus and the Berthlet Member assemblage, the shells are crushed and generally poorly preserved. A considerable amount of variation can be noted in the development of lateral slope plications, as has been described in many other species of *Leiorhynchus*. The dorsal profile also seems to be variable from almost quadrate to subelliptical. The shells are generally slightly wider than long, but this relationship frequently reverses itself. Undoubtedly, in many cases the variations noted are due to crushing.

The moderate size, flat upheld fold, shell angularity, and trifid median septum pattern in the brachial valve seem to separate clearly the Wisconsin form from *Leiorhynchus quadracostatus* (Vanuxem) as reported by Sartenaer (1961). In general outline, size, and plication development, *L. greeni* is comparable to *L. globuliformis* Hall and *L. mesacostalis* Hall from the Upper Devonian of New York. However, the low rounded plications and well defined sulcus of the Wisconsin forms appear to separate these species.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Fourteen specimens from M.P.M.—#387, and twelve specimens from M.-D.C.—#5116.

## Suborder ATRYPOIDEA Moore, 1952
## Superfamily ATRYPACEA Schuchert and LeVene, 1929
## Family ATRYPIDAE Gill, 1871
## Subfamily ATRYPINAE Waagen, 1883
## *Atrypa* Dalman, 1828

Type species—*Anomia reticularis* Linnaeus, 1767

*Atrypa* Dalman, 1828, Kongl. Svenska Vet. Akad. Handl., for 1827, p. 102; Hall, 1867, Pal. New York. 4: 312–314; Fenton and Fenton, 1932, Am. Mid. Natur. 13: 203–221.

Range: M. Silurian—L. Mississippian

### *Atrypa* sp. A
Pl. 4, figs. 1–4

Description: Shell moderate size for genus; suboval in dorsal outline, cardinal extremities bluntly rounded; strongly dorsi-biconvex in lateral profile, greatest convexity near midlength; pedicle beak extends slightly beyond brachial valve; anterior commissure rectimarginate to very slightly sinuate; average hinge line equals 80 per cent of greatest width; pedicle valve very slightly convex, greatest convexity at umbo; beak slightly extended, sharp, upturned;

foramen oval; moderately prominent cardinal area; brachial valve strongly convex, greatest height slightly posterior to midlength; strongly curved at umbo, slightly concave at cardinal extremities; surface marked by moderate, rounded plications; concentric growth lines, becoming slightly crowded near margins, very fine secondary concentric fila between major growth lines; primary plication on brachial valve in slight depression at umbo.

Dimensions: Average length 20.3 mm, average width 20.2 mm, average height of pedicle valve 3.7 mm, average height of brachial valve 6.6 mm; 8–10 plications per cm at anterior margin, primary growth lines 1–5 mm apart.

Discussion: All the moderately plicate atrypids in the Wisconsin section were previously considered to be *Atrypa reticularis*. However, due to the present complexity surrounding the systematics of the "*reticularis*" group, these distinctive Wisconsin forms are not given specific designation. *A.* sp. A can be distinguished from the rest of the assemblage by its moderately coarse ornament, suboval shape, dominant convex brachial valve, and the pedicle to brachial valve height ratio. The form varies in the degree of convexity of the pedicle valve (slightly convex to slightly concave) and in its suboval to triangular dorsal profile.

This form is similar in general appearance to *Atrypa waterlooensis*, *A. trowbridgei*, and *A. onusta* (Stainbrook, 1938). Although *A.* sp. A does approach *A. waterlooensis* in size and is often plano-convex, the average dimensions of the two forms show a distinct separation. In addition, *A.* sp. A never has less than 8 plications per cm at the anterior margin as compared to 4–8 plications per cm for this Iowa form. In general dorsal outline, *A. waterlooensis* is slightly less oval than *A.* sp. A. *A. trowbridgei* has a lower pedicle to dorsal valve height ratio, a more convex pedicle valve, a linguloid extension of its weak sinus, and a marked increase in the number and fineness of plications which distinguish it clearly from *A.* sp. A. The height of the brachial valve and a tendency to develop a bisinuate character in opposing valves at the anterior margin separate *A. onusta* from *A.* sp. A.

A clear separation can be observed when size characteristics of *Atrypa* sp. A are plotted against *A.* sp. B from the smallest to the largest shells. This separation is distinct in the comparison of the surface ornament, shape, and relative convexities of the two valves. Special attention was paid to the latter by the writer, with the conclusion that a significant difference is evident between the two forms when they reach approximately 10–14 mm in height. In *A.* sp. A, during this growth period, an obvious adjustment was made in the growth rates of the respective valves which caused a predominance in the convexity of the brachial valve. However, in *A.* sp. B, although a slight increase in the convexity of the brachial occurred, no drastic change in the growth rate of that valve is evident; in fact, the opposing valves seem to maintain a 1:1 convexity ratio from that period on, regardless of size (fig. 3).

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of the writer and M.P.M.—#16473$_1$, #19792$_3$.

## *Atrypa* sp. B

Pl. 4, figs. 5–8

*Atrypa reticularis* Whitfield, 1882, Geol. Wisconsin. 4: 333. pl. 26, fig. 6.
*Atrypa reticularis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 74. pl. 13, fig. 12, (not 13).

Description: Moderate size shells for genus; semielliptical to subrounded in dorsal outline; slight wings gently upturned; nearly equally biconvex in lateral profile, sharply curved at umbo of brachial valve; anterior margin rectimarginate to broadly uniplicate; hinge line averages approximately 80 per cent of shell width; pedicle valve moderately convex, greatest convexity at umbo; beak prominent, straight to moderately upturned, foramen oval; prominent broad sulcus common on specimens over 20 mm long; brachial valve moderately convex; anterior margin has broad low fold; surface marked by rounded, moderate plications; concentric growth lines close and regularly spaced, very fine secondary and tertiary concentric fila between major growth lines, primary plication on brachial valve in very slight depression at umbo.

Dimensions: Average length 17.5 mm, average width 18.3 mm, average height of pedicle

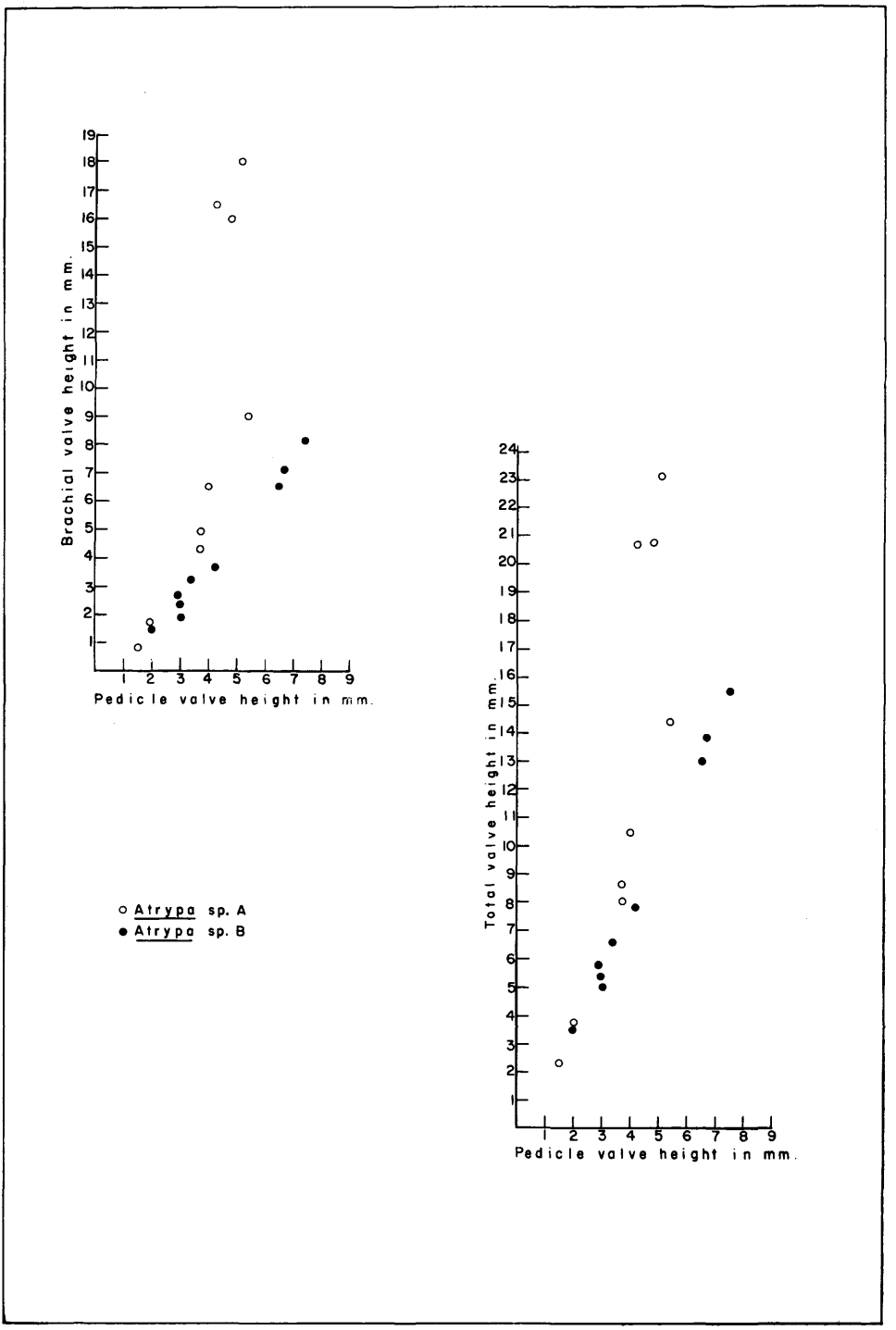


FIGURE 3. Scattergrams indicating significant variation in brachial height between *Atrypa* sp. A and *Atrypa* sp. B.

valve 4.6 mm, average height of brachial valve 4.6 mm; 12–22 plications per cm at anterior margin, primary concentric growth lines 1–3 mm apart.

Discussion: This form is easily distinguished in the Wisconsin section by its numerous rounded plications, equally biconvex shell, subrounded dorsal outline, and gently domed brachial valve. The greatest variation in the group occurs in the ontogeny of the shell, as the major convexity gradually switches from the pedicle to the brachial valve, the shell yet retaining a nearly equal biconvex nature.

The Wisconsin specimens show a great similarity to the Iowa species *Atrypa independensis* (Fenton and Fenton, 1935) and (Stainbrook, 1938), though the Iowa forms have sharper extremities and less regularly rounded lateral and anterior margins. The moderate and large specimens from the Milwaukee section appear to have a lesser tendency to develop an irregular anterior margin, but do possess broad folds which become more predominant on the larger shells. The alate growth lines on the Iowa forms are much more prominently developed than in the Wisconsin specimens, giving them an irregular appearance.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee, and the Belgium Member of the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Two specimens from M.-D.C. and collections of M.P.M.—#16473$_3$, #19792$_1$.

## *Atrypa* cf. *A. pronis* Fenton and Fenton, 1935
## Pl. 4, figs. 9–11

*Atrypa* sp. Fenton and Fenton, 1932, Am. Mid. Natur. v. 13, pl. 22, figs. 7–8.
*Atrypa pronis* Fenton and Fenton, 1935, J. Paleontol. 12: 240. pl. 32, figs. 5–9, 17, 18, 22, 26.

Description: Shells moderate size, subtriangular in dorsal outline, greatest width posterior to midlength; lateral margins almost straight curving gently toward blunt laterally compressed anterior margin; strongly dorsi-biconvex, umbo of brachial valve protruding over hinge line, strongly incurved brachial beak; anterior commissure strongly uniplicate; anterior portion of valve strongly upturned forming strong sulcus; brachial valve strongly convex; slight abbrieviated wings; bears strong narrow fold; surface marked by moderate rounded plications; concentric growth lines slightly crowded at margins.

Dimensions: Average length 31 mm, average width 31 mm, average height of pedicle

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EXPLANATION OF PLATE 4

FIGS. 1–4. *Atrypa* sp. A; 1–3, brachial, lateral, and anterior views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #19792$_3$, ×0.9; 4, brachial view of small shell, from same locality, M.P.M. #16473$_1$, ×3.6; p. 271.

5–8. *Atrypa* sp. B; 5–7, brachial, lateral, and anterior views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #19792$_1$, ×1.3; 8, brachial view of small shell, from same locality, M.P.M. #16473$_3$, ×3.6; p. 272.

9–11. *Atrypa* cf. *A. pronis* Fenton and Fenton, 1935; 9–11, brachial lateral, and anterior views, Milwaukee Formation, locality 3, M.-D.C. #5149, ×0.9; p. 274.

12–14. *Spinatrypa sinuata* Cleland, 1911; 12–14, brachial, lateral and posterior views of holotype, Lake Church Formation, locality 1, U.S.N.M. #85956, ×0.9; p. 276.

15–18. **Spinatrypa spinosa milwaukeensis** subsp. n; 15, latex cast of exterior, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #15251$_1$, ×1.3; 16, lateral view of holotype, from same locality, M.P.M. #20442, ×1.3; 17, lateral view of gibbose profile, from same locality, M.P.M. #15251$_e$, ×1.3; 18, interior pedicle view, from same locality, M.P.M. #20004, ×1.3; p. 276.

19–21. *Eosyringothyris occidentalis* (Swallow), 1860; 19–21, brachial, anterior, and lateral views, Lindwurm Member, Milwaukee Formation, M.P.M. #355, ×0.9; p. 277.

22, 23. *Eosyringothyris* sp. A; 22, 23, posterior and lateral views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16507, ×0.9; p. 278.

24–26. *Fimbrispirifer grieri* (Hall), 1867; 24, 25, pedicle and lateral views of type specimen, figure 25 shows concentric fila, Jeffersonville Formation, Falls of the Ohio, U.S.N.M. #51192, ×0.9; 26, pedicle view showing concentric fila in sulcus, Lake Church Formation, locality 1, U.S.N.M. #85970, ×0.9; p. .279

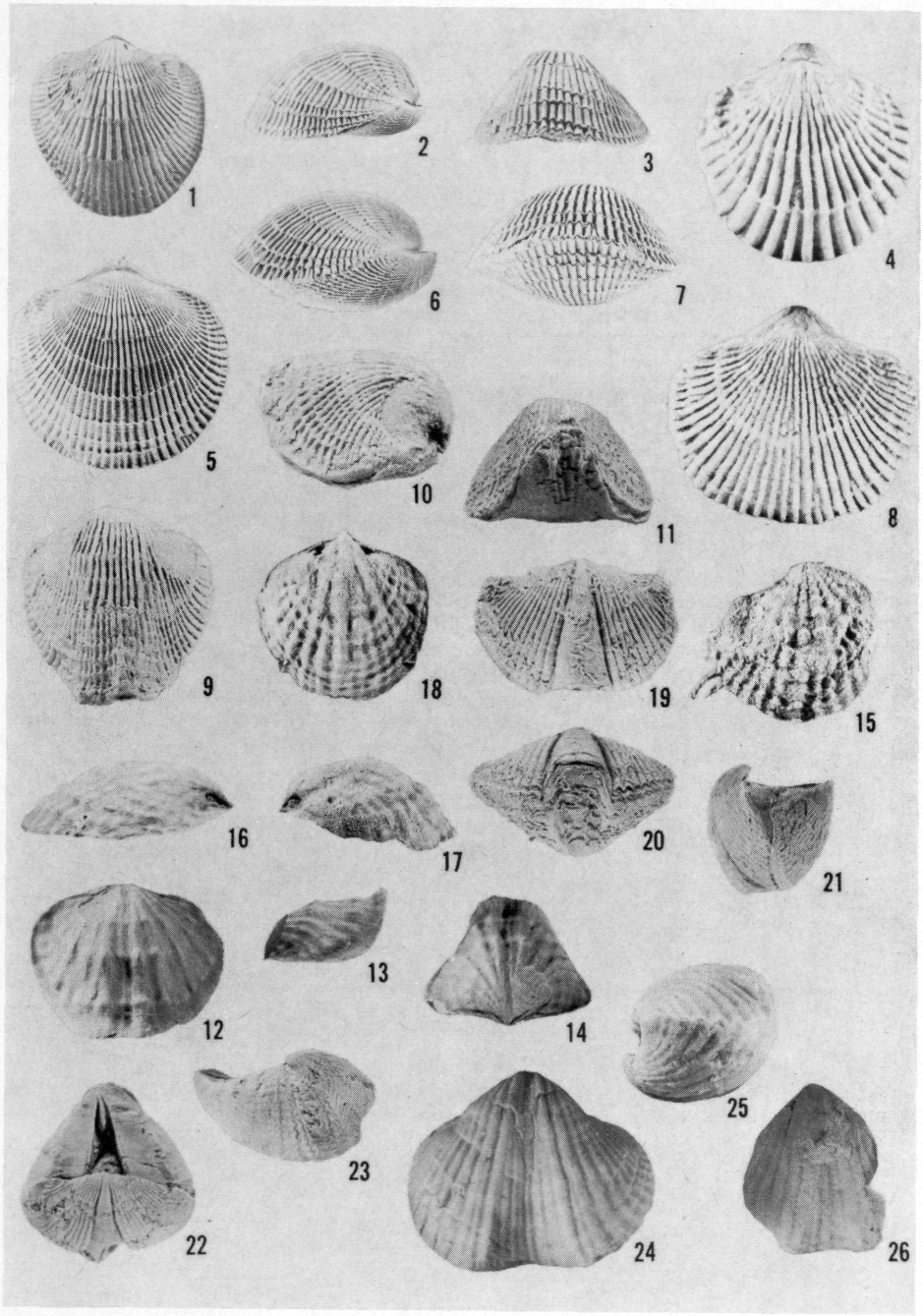


PLATE 4

valve 5.5 mm, average height of brachial valve 18 mm; average fold width 19 mm; 10 plications per cm at anterior margin; dimensions approximate.

Discussion: This form can be identified easily in the Wisconsin section by its strongly uniplicate anterior margin and subtriangular shape.

This form is described from only two poorly preserved specimens. The Wisconsin material is similar in form to *Atrypa lineata* Fenton and Fenton, 1935, in their elongate appearance and deep fold development. However, *A. lineata* has much finer and more numerous plications, and is longer than wide as compared to the nearly 1:1 ratio of *A. pronis*. The Wisconsin specimens are close to the Devonian Hackberry form *A. devoniana* Fenton and Fenton, 1924, in general shape, size, and fold development. The *A. devoniana* forms, however, are usually wider than long. There is a significant similarity between the Wisconsin material and *A. pronis* in the Iowa section, but, until further material becomes available, it is felt that no definite conclusion can be reached.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Two specimens from M.-D.C.—#5149.

## *Spinatrypa* Stainbrook, 1951

Type species—*Atrypa hystrix* var. *occidentalis* Hall, 1858
*Hystricina* Stainbrook, 1945, Geol. Soc. Am., Mem. 14: 49.
*Spinatrypa* Stainbrook, 1951, Wash. Acad. Sci. 41: 196.
Range: M. Devonian—Silurian

### *Spinatrypa sinuata* Cleland, 1911
Pl. 4, figs. 12–14

*Spinatrypa sinuata* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 75. pl. 13, figs. 17–19.

Description: Moderate size, strongly convex brachial valve cast; subtrapezoidal to suboval in dorsal outline, nearly straight cardinal margin leading to slightly extended rounded cardinal extremities; shell appears flattened along crest, concave along lateral slopes; margins appear flattened; anterior margin bears broad, exaggerated fold; moderate to sharply rounded umbo gently increasing in height toward anterior margin, becoming sharply elevated slightly posterior to front of shell, greatest height at anterior margin; surface ornamented by subrounded costae with intercalating ribs near midlength; shallow trough at crest of shell which widens anteriorly, trough bears median low, well defined costella; strong concentric growth lines cross costae causing nodes to develop at intersections.

Dimensions: Average length 20.0 mm, average width 25.3 mm, average height 9.8 mm; average fold width 15.0 mm; 20–24 costae on brachial valve, concentric growth lines 3–4 mm apart at midlength of shell, trough at crest of shell widens anteriorly from 1 mm at umbo to 3–4 mm at anterior margin.

Discussion: These forms are clearly distinct from every other form in the Wisconsin assemblage. Their similarity to *Spinatrypa* seems quite strong, but, because of the exaggerated fold, their true generic relationship is yet to be decided. The forms are closest to *S. spinosa milwaukeensis* in strength and shape of surface ribs, though the fold characteristic obviously separates them. So far only two specimens have been collected from the Wisconsin section, with very little variation noted between them.

Occurrence: Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Two specimens from U.S.N.M.—#85956.

### **Spinatrypa spinosa milwaukeensis** subsp. n.
Pl. 4, figs. 15–18

*Atrypa hystrix* Whitfield, 1882, Geol. Wisconsin. 4: 333. pl. 26, fig. 5.
*Atrypa hystrix* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 73. pl. 13, figs. 14–16.

Description: Moderate to small shells for genus; semielliptical in dorsal outline, posterior margin slopes gently to moderately rounded cardinal extremities; slightly dorsi-biconvex, greatest height near midlength, very slightly flattened at extremities; anterior margin rectimarginate to very slightly sinuate; pedicle valve slightly to moderately convex, greatest convexity appears to be at umbo; diductor and adductor muscle scars generally poorly defined;

brachial valve moderately convex, greatest convexity near center of shell; diductor muscle scar divided by median septum, fades anteriorly; surface marked by broad, subround plications; radial ornament crossed by strong, concentric growth lines which become lamellose near margins giving thin leafy appearance over plications; on occasion distinct spines are present along margins (plate 4, fig. 15).

Dimensions: Average length 15.2 mm, average width 15.7 mm, average height 3.8 mm; diductor muscle scar approximately 7 mm wide; 6–8 plications per cm at anterior margin, up to 1 mm wide; holotype—#20442, length 22.0 mm, width 22.0 mm, height 6.5 mm.

Discussion: The lack of sufficient well preserved specimens does not allow a significant discussion of variations, with the exception that one specimen (plate 4, fig. 17) shows an unusually robust shell, yet is similar in all other respects. The Wisconsin form bears a general resemblance to the Iowa coarsely plicate *Spinatrypa rockfordensis* (Fenton and Fenton), 1924, but appears proportionately much longer than that Upper Devonian form. The Iowa forms *S. trulla* (Stainbrook), 1945, and *S. occidentalis* (Stainbrook, 1938) are similar in outline and surface ornament, but they differ considerably in being more robust and possessing a distinct sulcus *S. mascula* (Stainbrook), 1938, has a similar appearance to *S. spinosa milwaukeensis*, but shows a distinctly more robust shell with fewer plications. The Wisconsin specimens show a definite relationship to *S. spinosa* (Hall), 1867, in lateral and dorsal outlines and in the possession of 20–25 plications that bifurcate at the center of the shell. The Wisconsin shells seem to have slightly more extended cardinal extremities than *S. spinosa*; the value of such a subtle variation in a relatively small assemblage is admittedly questionable. It seems quite possible the Wisconsin and possibly other allied midwest forms are subspecific populations developed in localized environments from a wide distribution of the Middle Devonian ancestor *S. spinosa*, from New York and southern Canada across the north-central portion of the United States.

Occurrence: Berthlet Member of the Milwaukee Formation at Estabrook Park, Milwaukee, and the Belgium Member of the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collections of M.P.M.—#15251, #20004, #20442.

## Suborder SPIRIFEROIDEA Allen, 1940
## Superfamily SPIRIFERACEA Waagen, 1883
## *Eosyringothyris* Stainbrook, 1943

Type species—*Spirifer asper* Hall, 1858
*Eosyringothyris* Stainbrook, 1943, J. Paleontol. 17: 431, 432.

Diagnosis: Spiriferoid shells of moderate size; ventri-biconvex; wider than long; pedicle valve strongly convex, subpyramidal; cardinal area triangular, flat to gently concave, strongly procline to apsacline; brachial valve moderately convex, moderate unplicated fold, cardinal process subquadrate, strong crural plates, low strong median ridge; surface marked by narrow subangular plications, and numerous occasionally spiney irregular papillae.

Discussion: It was noted in plotting the characteristics of the spiriferoid specimens from the Wisconsin section that the width and fold width dimensions proved most distinctive and useful in separating *Eosyringothyris* from the rest of the assemblage.

Range: Devonian.

### *Eosyringothyris occidentalis* (Swallow), 1860
### Pl. 4, figs. 17–21

*Cyrtia occidentalis* Swallow, 1860, St. Louis Acad. Sci. Trans. 1: 648, 649.
*Spirifera (Cyrtina) aspera* Whitfield, 1882, Geol. Wisconsin. 4: 331, 332. pl. 26, figs. 1, 2.
*Cyrtina occidentalis* Miller, 1889, N. Am. Geol. and Paleontol. p. 343.
*Spirifer asper* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 76, 77. pl. 16, figs. 1–5.
*Syringothyris occidentalis* Branson, 1923, Mo. Bur. Geol. and Mines. 2nd ser., 17: 103. pl. 20, figs. 3–5, (not pl. 21, figs. 1–3).
*Eosyringothyris occidentalis* Stainbrook, 1943, J. Paleontol. 17: 437, 438. pl. 69, figs. 1–5.

Description: Moderate shells for genus; subelliptical to semi-circular in dorsal outline, posterior margin slightly concave on either side of small brachial valve beak, hinge line straight; ventri-biconvex in lateral profile, greatest height posterior to midlength; cardinal extremities

slightly mucronate, greatest width at hinge line; anterior commissure strongly uniplicate; pedicle valve strongly convex, pyramidal in posterior outline; cardinal area broadly triangular, long narrow delthyrium with recessed floor at ventral portion of slit; distinct, subround to squared sulcus begins at beak; brachial valve moderately convex; greatest convexity at umbo; beak extends strongly beyond hinge line, exposing open notothyrium; moderate, squared to subrounded fold extends from beak to anterior margin; surface marked by moderate rounded plications, fine concentric growth lines, and numerous granules which seem to be parallel, and aligned concentrically.

Dimensions: Average length 19.0 mm, average width 31.6 mm, average height 18.0 mm, average fold width 8.3 mm, average fold height 3.9 mm; 16–19 plications on each side of fold and sulcus.

Discussion: These shells are distinguished by their high flat cardinal areas, broad shells, flattened folds, and granulose surface. A certain amount of variation was noted in the square to subrounded fold profile, and blunt to slightly mucronate wing development.

The Wisconsin forms are similar to *Eosyringothyris asper* (Stainbrook, 1943) but have a narrower, smaller shell, and a catacline rather than procline cardinal area. There also is a similarity to *E. calvini* Stainbrook, 1943, but the Milwaukee specimens are smaller, catacline, and less mucronate.

Occurrence: The Lindwurm Member of the Milwaukee Formation at the North Avenue Intake Tunnel, Milwaukee, and the Lindwurm and Berthlet members of the same formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.–D.C. and M.P.M.—#355.

### *Eosyringothyris* sp. A
### Pl. 4, figs. 22, 23

Description: Moderate size shells for genus; posterior margin slightly convex due to slightly extended beak, hinge line straight, lateral margins regularly curved, anterior margin nearly straight, slight notch developes at fold along anterior margin; ventri-biconvex in lateral profile; greatest width just posterior to midlength; anterior margin uniplicate; pedicle valve strongly convex, pyramidal in posterior outline; cardinal area acutely triangular, straight to slightly twisted posteriorly extended beak, slopes sharply to all margins, long narrow open delthyrium; moderate subrounded sulcus begins at beak; brachial valve moderately convex, greatest convexity at umbo, slopes regularly to all margins, crest of shell marked by moderate subrounded fold; beak extends slightly beyond hinge line; surface marked by low rounded plications, moderate to strong concentric growth lines which imbricate strongly near margins, and numerous granules with slight concentric alignment.

Dimensions: Average length 18.0 mm, average width 30.2 mm, average height 25.1 mm, average fold width 9.1 mm, average fold height 4.4 mm; 16–19 plications on each side of fold and sulcus.

Discussion: These forms are distinguished by their high relatively narrow pedicle valves and granulose surface. Only three well preserved specimens of this form were available, so no significant variation was noted.

The Wisconsin forms are similar to *Eosyringothyris thomasi* Stainbrook, 1943, in brachial valve convexity, but differ from that Iowa species in having a procline cardinal area and a narrower shell. *E. calvini* Stainbrook, 1943, can be separated from *E.* sp. A because of its wider and more gibbose shell. Additional good material is needed to correctly identify these seemingly mature forms.

Occurrence: Lindwurm Member of the Milwaukee Formation of Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.–D.C. and M.P.M.—#16507.

## Family SPIRIFERIDAE King, 1846
### *Fimbrispirifer* Cooper, 1942

Type species—*Spirifer venutus* Hall, 1857
*Fimbrispirifer* Cooper, 1942, Wash. Acad. Sci. 32: 231, 232.
Range: M. Devonian

## *Fimbrispirifer grieri* (Hall), 1867
Pl. 4, figs. 24–26

*Spirifer grieri* Hall, 1867, Pal. New York. 4: 194, 195. pl. 27, fig. 29, pl. 28, figs. 17–23.
*Spirifer* sp. nov. Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 82. pl. 14, figs. 13, 14.

Description: Casts of pedicle valves of moderate shells for genus; suboval to subtriangular in pedicle outline, posterior lateral margins nearly straight to slightly concave on either side of strongly extended pedicle beak, slightly concave at sulcus; cardinal extremities slightly developed; greatest width apparently slightly posterior to midlength; shell moderately convex, broad low rounded sulcus from beak to anterior margin; muscle scar distinct at beak and along outer margin at diverging dental lamellae; surface marked by moderate rounded plications over sulcus and lateral slopes, plications intercalate in sulcus, regular fine concentric fila over entire shell, (plate 4, figs. 25, 26) occasionally prominent.

Dimensions: Length 18–25 mm, approximate width 20–28 mm, fold width 10–13 mm; 7–10 plications on each side of sulcus, 4–8 in sulcus, 3–5 concentric fila per mm near anterior margin, dental lamellae approximately 7 mm long.

Discussion: These forms can be easily distinguished from any other Wisconsin spiriferid because of their subtriangular to suboval dorsal outline, and plicated sulcus. Very little variation was noted in the few available specimens; the pattern of the plications in the sulcus seemed quite variable in number and regularity, whereas the lateral plications were quite regular.

The Wisconsin forms are similar to *Fimbrispirifer divaricatus* (Hall), 1867, in general surface ornament and dorsal profile; however, *F. grieri* is less robust and has a lower cardinal area, a lower less angular fold, and much broader and fewer plications on the slopes and fold.

Occurrence: Lake Church Formation at Lake Church, Wisconsin.

Catalgoue specimens: Four specimens from U.S.N.M.—#85970; type specimen of *F. grieri* U.S.N.M.—#51192.

## *Mucrospirifer* Grabau, 1931

Type species—*Delthyris mucronata* Conrad, 1841
*Mucrospirifer* Grabau, 1931, Nat. Univ. Peking Sci. Quart. 2: 247, 248; Stumm, 1956, Mus. Pal. Univ. Mich. Contr. 13(3): 81–94. 3 pls., 60 figs.
Range: M. and U. Devonian

## *Mucrospirifer* sp. A
Pl. 5, figs. 1, 2

*Spirifer mucronatus* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 80, 81. pl. 16, figs. 12–14.

Description: Moderate size shells for genus; submucronate to semicircular in dorsal outline; posterior margin slightly concave on either side of slightly extended beak, cardinal extremities slightly extended; slight concavity at anterior margin in dorsal profile due to fold development; shells nearly equally biconvex in lateral profile, ventral valve slightly dominant; anterior margin moderately uniplicate; greatest width at or equal to hinge line; greatest height slightly posterior to midlength; pedicle valve moderately convex, greatest convexity at umbo; moderate rounded sulcus; narrow concave cardinal area, beak erect to slightly overturned; brachial valve moderately convex, greatest convexity at umbo, low subrounded fold extends from beak to anterior margin; surface marked by subangular plications and numerous, imbricating concentric lamellae.

Dimensions: Length 13.6–10.5 mm, width 20–48 mm, height 10–8 mm, fold width 6.4–6.0 mm, fold height 2.5–2.0 mm; 10–20 plications on either side of fold, 4–5 concentric lamellae per mm; interarea 1–2 mm high.

Discussion: Only two specimens were discovered in the Wisconsin section representing this species of *Mucrospirifer*. Although the specimens examined exhibited considerable variation, especially in relation to their length-width ratio, and modest to very mucronate cardinal extremities, these variations are felt to represent characteristics of the same species because of their other significant similarities, in cardinal area, convexity, and ornament.

*Mucrospirifer* differs from *Tylothyris subvaricosa umbonata* of the Wisconsin section in lacking a strongly protruding pedicle beak and in possessing a distinctly shorter interarea and more extended cardinal extremities. *M.* sp. A is similar in dorsal outline and beak development to *T.*? cf. *T. bimesialis* of the Milwaukee Formation, but differs significantly in lateral profile. There is a similarity between the Wisconsin form and *M. mucronatus* (Hall, 1867), but, since Hall's form is no longer designated as that species (Stumm, 1956) and due to the lack of sufficient material, it was felt that no specific name should be applied to the Wisconsin forms at present.

Occurrence: The North Point Member of the Milwaukee Formation at the North Avenue Intake Tunnel, Milwaukee, and the Lindwurm Member of the same formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collection of M.P.M.—#358.

## *Spinocyrtia* Fredericks, 1916

Type species—*Delthyris granulosa* Conrad, 1839

*Spinocyrtia* Fredericks, 1916, Mem. Comm. Geo. n. ser., livr. 156: 18; Stainbrook, 1943, J. Paleontol. 17: 419–421.

Range: M. Devonian

### **Spinocyrtia clelandi** sp. n.

Pl. 5, figs. 3–6

*Spirifera angusta* Whitfield, 1882, Geol. Wisconsin. 4: 329, 330. pl. 26, fig. 3.

*Spirifer iowensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 79. pl. 17, figs. 3, 5, (not 4).

Description: Moderate size shells for genus; broadly triangular in dorsal outline, posterior margin slightly concave on either side of pedicle beak, hinge line straight, to mucronate cardinal extremities, anterior margin gently curved to straight; nearly equally biconvex, greatest height posterior to midlength; greatest width along hinge line; anterior commissure moderately uniplicate; pedicle valve moderately convex, greatest convexity at umbo; moderate rounded sulcus; cardinal area broadly triangular, slightly concave posteriorly; delthyrium broadly triangular; interior of pedicle valve displays distinct central muscle scar and long thin dental lamellae; brachial valve moderately convex, greatest convexity at strongly curved umbo, beak extends prominently beyond hinge line, shells slightly concave at cardinal extremities; moderately broad, rounded fold becomes well defined near anterior portion of umbo in lateral profile, crest of fold bears low trough which loses its identity near anterior margin; surface ornamented by moderate rounded plications, fine radial and concentric fila form small

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EXPLANATION OF PLATE 5

FIGS. 1, 2. *Mucrospirifer* sp. A; 1, 2, brachial and lateral views, Milwaukee Formation, M.P.M. #358, ×1.3; p. 279.

3—7. **Spinocyrtia clelandi** sp. n.; 3, interior pedicle view, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #20449, ×0.9; 4, 5, 7, lateral, brachial, and anterior views of holotype, from same locality, M.P.M. #16580, ×1.3; 6, enlargement of surface ornament, M.P.M. #16580, ×4.5; p. 280.

8, 9. *Spinocyrtia iowensis* (Owen), 1852; 8, 9, brachial and lateral views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16527, ×0.9; p. 282.

10–12. *Spinoyrtia milwaukeensis* (Cleland), 1911; 10, 11, brachial and anterior views, Lindwurm Member, Milwaukee Formation, M.P.M. #341, ×0.9; 12, lateral view, from same member, M.P.M. #342, ×0.9; p. 283.

13–15. *Tylothyris* cf. *T. bimesialis* (Hall), 1858; 13–15, brachial, lateral and anterior views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #359, ×1.8; p. 283.

16–19. **Tylothyris subvaricosa umbonata** subsp. n.; 16, 18, brachial and lateral views of holotype, Lindwurm Member, Milwaukee, Formation, M.P.M. #M3 (designated by writer), ×1.8; 17, 19, anterior and lateral views of smaller shell indicating emphasis in pedicle valve growth, from same member, M.P.M. #M2, ×1.8; p. 284.

20, 21. *Elytha* cf. *E. subundifera* (Meek and Worthen), 1868; 20, 21, lateral and pedicle views, Milwaukee Formation, M.-D.C. #5207, ×0.9; p. 285.

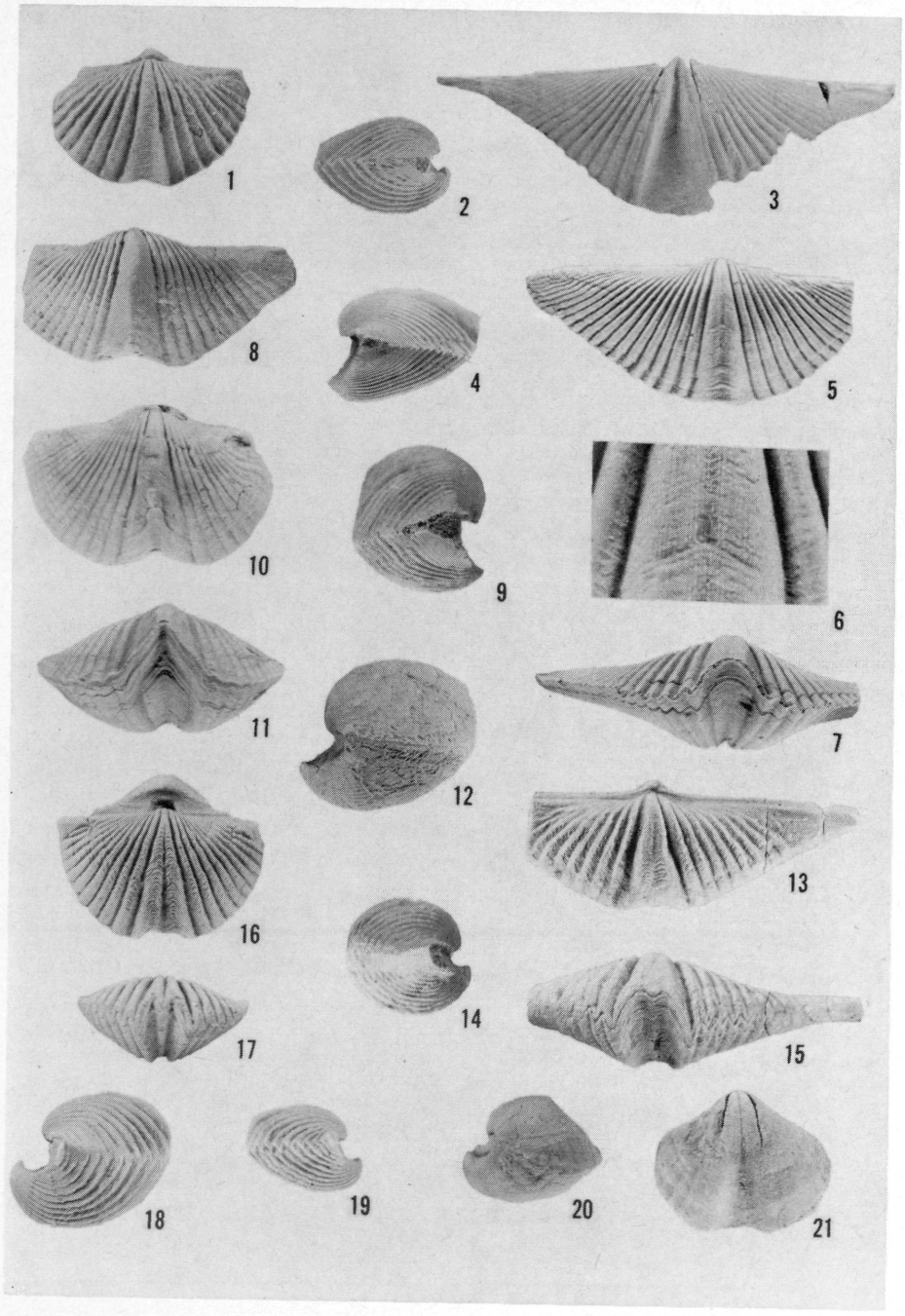


PLATE 5

pustules at the points of intersection, occasional stronger growth lines give slight lamellose appearance near margins.

Dimensions: Average length 22.9 mm, average width approximately 47 mm, average height 16.3 mm, average fold width 11.3 mm, average fold height 5.1 mm; 16–25 plications on each side of fold and sulcus; holotype #16580—length 16.5 mm, width approximately 40 mm, height 12 mm.

Discussion: This form is distinguished by its relatively flat appearance, thin margins, distinct secondary ornamentation, and moderate rounded fold and sulcus. These shells also display the variation in length to width ratio as noted in the discussion of *Spinocyrtia iowensis*, but seem to show a less exaggerated variation. The distinct trough on the crest of the fold in the figured shell is not well defined on all specimens.

The Wisconsin species is similar to *Spinocyrtia cedarensis* (Stainbrook, 1943) in general shape and fold development, but it can be distinguished from that Iowa form because of its shorter, flatter shell and more distinctly rounded sulcus. *Spirifer angusta* Hall, 1867, has a comparable shape and fold development, but lacks the distinct surface ornament, posteriorly directed cardinal area, and nearly equal ventri-convex lateral profile of *S. clelandi*.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.-D.C. and M.P.M.—#16580, #20449.

## *Spinocyrtia iowensis* (Owen), 1852
Pl. 5, figs. 8, 9

*Spirifer iowensis* Owen, 1852, Geological Survey of Wisconsin, Iowa and Minnesota. p. 585. pl. 3, fig. 1.
*Spirifer pennatus* Owen, 1852, Geological Survey of Wisconsin, Iowa and Minnesota. p. 585. pl. 3, figs. 3, 8.
*Spirifer ligus* Owen, 1852, Geological Survey of Wisconsin, Iowa and Minnesota. p. 585. pl. 3, figs. 4, pl. 3a, fig. 2.
*Spirifer pennatus* Hall, 1858, Geol. Sur. Iowa. 1(2): 510, 511. pl. 5, fig. la-i.
*Spirifer atwaterana* Miller, 1878, Davenport Acad. Sci. Proc. 2: 222.
*Spirifer pennata* Whitfield, 1882, Geol. Wisconsin. 4: 330, 331. pl. 26, fig. 4.
*Spirifer iowensis* Schuchert, 1897, U.S. Geol. Surv. Bull. 87: 393.
*Spirifer iowensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 79. pl. 17, fig. 4, (not 3, 5).
*Platyrachella iowensis* Belanski, 1928, Am. Midl. Natur. 11: 167.
*Spinocyrtia iowensis* Stainbrook, 1943, J. Paleontol. 17: 421–423. pl. 65, fig. 1–5, text figs. 4–6.

Description: Shells moderate to large for genus; semielliptical to broadly triangular in dorsal outline, posterior margin concave on either side of strongly extended brachial beak to mucronate cardinal extremities, anterior margins flat to concave due to high fold; shell nearly equally biconvex; greatest height slightly posterior to midlength; greatest width along hinge line; anterior commissure strongly and sharply uniplicate; pedicle valve moderately to strongly convex, greatest convexity slightly anterior to umbo; deep angular sulcus; cardinal area straight, broadly triangular, concave posteriorly; brachial valve moderately to strongly convex, greatest convexity at umbo, beak extends strongly beyond hinge line; crest of high sharp fold nearly parallels brachial valve profile, some specimens bear slight depression along fold at umbo; surface ornamented by low to moderate rounded plications, very fine radial fila and concentric growth lines become slightly lamellose near margins.

Dimensions: Average length 25.5 mm, average width approximately 60 mm, average height 24.8 mm, average fold width 13.1 mm, average fold height 9.4 mm; 15–25 plications on each side of fold and sulcus.

Discussion: These large spiriferid shells are distinguished by their short, strongly convex shells, weak secondary ornamentation, and vertically truncated high angular fold and sulcus. One brachial valve measured approximately 90 mm in width (another was reported by Cleland to be 7 inches wide), making these the largest brachiopods in the Wisconsin Devonian. Although the shells are all considerably wider than long, with the greatest width along the hinge line, the length-to-width ratio differs for almost every specimen, which apparently indicates the variability within this species.

The Wisconsin specimens show an ususually strong similarity to the Iowa forms of this

species in almost every respect. *Spinocyrtia iowensis* can be distinguished from *S. milwaukeensis* by its shorter shell, stronger radial plications, and exaggerated cardinal extremities, which the latter form was not noted to possess. *S. clelandi* can be separated because of its flatter shell, more shallow and rounded fold and sulcus, less concave cardinal area, and stronger secondary granulose surface marking.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.-D.C. and M.P.M.—#16527.

### *Spinocyrtia milwaukeensis* (Cleland), 1911
### Pl. 5, figs. 10–12

*Spirifera euruteines* var. *fornacula* Whitfield, 1882, Geol. Wisconsin. 4: 330. pl. 25, fig. 22.
*Spirifer euryteines* var. *milwaukeensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 77, 78. pl. 15, figs. 1–6.

Description: Moderate size shells for genus; subelliptical to subrectangular in dorsal outline, posterior margin slightly concave on either side of extended beak, hinge line straight to slightly extended cardinal extremities, anterior margin concave due to height of fold; nearly equally biconvex, greatest height slightly posterior to midlength; greatest width at or equal to hinge line; anterior commissure moderately uniplicate; pedicle valve strongly convex, greatest convexity at umbo, flattened at cardinal extremities, sulcus deep, angular, begins at suberect beak; broad triangular cardinal area, concave posteriorly; brachial valve strongly convex, greatest convexity at umbo, umbo strongly curved extending beyond hinge line, moderate broad, angular fold becomes defined at umbo in lateral profile, follows general lateral outline of brachial valve, crest of fold flattens posteriorly and bears slight trough over umbo; surface marked by low rounded plications, fine radial and concentric fila, concentric markings slightly dominant, become lamellose near margins.

Dimensions: Average length 23.9 mm, average width 39.9 mm, average height 20.1 mm, average fold width 8.1 mm, average fold height 7.0 mm; 11–16 plications on each side of fold and sulcus.

Discussion: *Spinocyrtia milwaukeensis* can be distinguished by its subelliptical outline, slightly extended cardinal extremities, pedical valve height, and moderate angular fold. The dorsal profile varies slightly, depending on the extension of the cardinal extremities.

This form as described by Cleland is felt to be a distinct species rather than a variety of *Spinocyrtia euryteines*, because it lacks the broad low fold, lacks strong radial fila, and possesses more strongly rounded plications than that Iowa form. *S. milwaukeensis* shows some similarity to *S. brandonensis* (Stainbrook, 1943), but has a more distinct fold and sulcus and has less extended cardinal extremities. The Wisconsin form differs from *S. parrayanus* (Stainbrook, 1943) in having a more angular but lower fold and a less incurved pedicle beak. In dorsal outline and fold development, *S. milwaukeensis* is similar to *Spirifer granulifera* Hall, 1867, but it does not have the strong pustulose surface or the greatly incurved beak of that form.

Occurrence: All members of the Milwaukee Formation at North Avenue Intake Tunnel and at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.-D.C. and M.P.M.—#341, #342.

### *Tylothyris* North, 1920

Type species—*Cyrtia laminosa* McCoy, 1844
*Tylothyris* North, 1920, Geol. Soc. London Quart. J. 76: 195–197; Stainbrook, 1943, J. Paleontol. 17: 438.
Range: U. Devonian—Mississippian

### *Tylothyris?* cf. *T. bimesialis* (Hall), 1858
### Pl. 5, figs. 13–15

*Spirifer bimesialis* Hall, 1858, Geol. Sur. Iowa. 1(2): 507. pl. 4, fig. 6.
*Tylothyris bimesialis* Stainbrook, 1943, J. Paleontol. 17: 438, 439. pl. 69, figs. 9–15.

Description: Moderate size shell for genus; broadly triangular in dorsal outline, hinge

line straight, slightly concave anterior margin at fold and sulcus; greatest height at midlength, nearly equally biconvex, shell nearly circular in lateral profile; greatest width at hinge line; anterior commissure biplicate; pedicle valve moderately convex; sulcus moderately deep, bears single plication; cardinal area concave, long, narrow, margins nearly parallel, delthyrium open; brachial valve moderately convex; broad low fold indistinct in lateral profile, bears single trough which extends from beak to anterior margin; surface ornamented by subangular plications, numerous, imbricating posteriorly directed, concentric lamellae.

Dimensions: Length 10.4 mm, approximate width 35 mm, height 8.2 mm, fold width 5.9 mm, fold height 2.5 mm; 10–12 plications on each side of fold, 6–7 concentric lamellae per mm at anterior margin.

Discussion: This single form can be distinguished from *Tylothyris subvaricosa umbonata* of the Wisconsin section because of its mucronate outline, large size, round lateral profile, and less distinct median fold depression. The round lateral profile and significantly depressed fold separate this form from *Mucrospirifer* sp. A, also of the Wisconsin section. This Wisconsin form can be separated from *T. subattenuata* (Stainbrook, 1943) because of its more mucronate cardinal extremities and its higher, less curved cardinal area.

Since this form is represented by a single specimen exposing only its external features, its true generic relationship is uncertain. Due to its close external similarity with *T. bimesialis* (Stainbrook, 1943), it is tentatively placed under that genus until the discovery of further material can reveal the presence of an apical callosity and related strong medium septum.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimen: One specimen form M.P.M.—#359.

## **Tylothyris subvaricosa umbonata** subsp. n.

Pl. 5, figs. 16–19

*Spirifer subvaricosa* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 81, 82. pl. 16, figs. 6–11.

Description: Small to moderate shells for genus; semielliptical to subcircular in dorsal outline, slight wings developed, anterior margin convex to concave as fold in larger specimens causes concavity at anterior in dorsal outline; ventri-biconvex in lateral profile, greatest height near midlength; slightly truncate in anterior lateral profile; greatest width at hinge line; anterior commissure moderately biplicated; pedicle valve strongly convex, greatest convexity at umbo, moderate sulcus bears single plication from front of umbo to anterior margin; beak suberect to erect; cardinal area broadly triangular, strongly concave posteriorly; triangular delthyrium open; brachial valve moderately convex, greatest convexity at umbo, beak extends beyond hinge line; fold low, bears median sulcus; surface marked by subangular plications, and numerous imbricating posteriorly directed concentric lamellae.

Dimensions: Average length 7.3 mm, average width 11.7 mm, average height 6.1 mm, average fold width 3.9 mm, average fold height 1.9 mm; 7–11 plications on each side of fold, 4–6 concentric lamellae per mm at anterior margin; holotype #M3—length 10.8 mm, width 16.2 mm, height 10.4 mm.

Discussion: These distinct forms can be separated from other brachiopods in the Wisconsin section because of their extended pedicle beak, lamellose surface ornament, sulcate fold, and size. Most of the variation seems to be due to the age of the shell. The smaller shells are more circular and are more evenly biconvex; the pedicle valve seems to show a faster increase in height.

The Wisconsin forms are very similar to *Tylothyris consobrinus* (Hall and Clarke, 1892) in general shape and appearance; however, *T. subvaricosa umbonata* is considerably smaller and has a more distinct median sulcate fold. *Spirifer consors* (Ehlers and Kline, 1934) has a similar outline, but is larger and has a less distinct concentric ornament and median sulcus in the fold than the Wisconsin specimens. The Iowa form *T. randalia* Stainbrook, 1943, has a similar general appearance and brachial valve profile, but differs in being smaller and having a shorter cardinal area. *T. subvaricosa* (Stainbrook, 1941) is comparable to the Wisconsin specimen in

size, dorsal outline, and plication development, but this Iowa form has a higher cardinal area, a less prominent pedicle beak, a stronger higher brachial beak, and fewer plications.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of the writer, M.-D.C. and M.P.M. Unnumbered M.P.M. specimens designated M3 and M2 by writer.

## Subfamily ELYTHINAE Fredericks, 1924

### *Elytha* Fredericks, 1918

Type species—*Delthyris fimbriatus* Conrad, 1842

*Elytha* Fredericks, 1918, Russian Pal. Ann. 2: 87; Stainbrook, 1940, Am. Mid. Natur. 24(2): 414.

Range: Devonian

### *Elytha* cf. *E. subundifera* (Meek and Worthen), 1868

Pl. 5, figs. 20, 21

*Spirifer subundifera* Meek and Worthen, 1868, Ill. Geol. Surv. 3: 434, 435. pl. 10, figs. 5a-e.
*Reticularia fimbriata* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 82, 83.
*Elytha subundifera* Stainbrook, 1940, Am. Mid. Natur. 24(2): 414, 415. pl. 1, figs. 1-5, 7, 8, pl. 2, fig. 8.

Description: Internal casts of moderate size shells for genus; suboval to subelliptical in dorsal outline, lateral wings rounded, anterior margin slightly curved to concave depending on development of fold and sulcus; greatest height and width near midlength, shell nearly equally biconvex; hinge line averages slightly more than two-thirds of width; anterior commissure broadly uniplicate; lateral and anterior margins flattened; pedicle valve moderately convex, greatest convexity at umbo; beak erect to slightly overturned; moderate rounded sulcus; cardinal area short, strongly curved, delthyrium broadly triangular; cast of interior displays long, thin slightly diverging dental lamellae, sulcus over umbo bears low median ridge; brachial valve moderately convex, greatest convexity at umbo, brachial beak extends slightly beyond hinge line; broad rounded fold begins at beak; surface marked by low rounded plications and occasionally pronounced concentric growth lines.

Dimensions: Length 22–32 mm, width 29–43.3 mm, height 17.5–22 mm, fold width 9–15 mm, fold height 11 mm; 6–7 plications on each side of fold and sulcus.

Discussion: These shells are distinguished in the Wisconsin section because of their suboval outline, small strongly curved cardinal areas, and few low rounded plications. The only significant variation noted was in the development of dorsally suboval and rounded cardinal extremity profiles by the posterior extension of the pedicle beak.

The Wisconsin forms are similar to *Elytha johnsonensis* Stainbrook, 1940, in surface ornament and general appearance; however, the average larger size, lack of a well defined sulcus, subpentagonal outline, and thinner shell separate that Iowa species from *E.* cf. *E. subundifera*. *E. fimbriatus* (Hall, 1867) is similar to the Wisconsin specimens, but differs in being less subtriangular and having a lesser length-to-width ratio.

Occurrence: Berthlet Member of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.P.M. and M.-D.C.—#5207.

## Superfamily ROSTROSPIRACEA Schuchert and LeVene, 1929
## Family ATHYRIDAE Davidson, 1884
## Subfamily ATHYRINAE Waagen, 1883

### *Athyris* McCoy, 1844

Type species—*Terebratula concentrica* Von Buch, 1834

*Athyris* McCoy, 1844, Carb. Fossils Ireland. p. 128, 146; Hall and Clarke, 1894, Pal. New York. 8(2): 83–90.

Range: M. Devonain—Mississippian

## *Athyris vittata randalia* Stainbrook, 1942
## Pl. 6, figs. 1–6

*Athyris fultonensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 83, 84. pl. 14, figs. 1–4.

*Athyris vittata randalia* Stainbrook, 1942, J. Paleontol. 16: 616, 617. pl. 89, figs. 1–6.

Description: Moderate to small shells for genus; subpentagonal to subquadrate in dorsal outline, posterior lateral margins nearly straight to slightly curving in small to large shell, while anterior lateral margins reverse this profile, anterior margin nearly straight to gently curved; hinge line equals 80 per cent of width of shell, greatest width slightly anterior to midlength; nearly equally biconvex in lateral profile, pedicle valve slightly dominant; anterior commissure broadly uniplicate; greatest height slightly posterior to midlength; pedicle valve moderately convex, greatest convexity at umbo; anterior portion of shell marked by slight, broad, rounded sulcus which extends from margin to midlength; beak suberect, moderate circular foramen, brachial valve moderately convex, greatest convexity at umbo, slight troughs develop on each side of broad fold which seem to exaggerate on the large shells; surface marked by crenulate concentric, growth lines which become slightly imbricated near margins.

Dimensions: Average length 10.1 mm, average width 10.4 mm, average height 6.3 mm, average fold width 7.5 mm; growth lamellae 0.1 mm apart at margins to 1 mm apart at umbo.

Discussion: These forms are very distinctive in the Wisconsin section because of their plicate commissure and crenulate surface ornament. A considerable amount of variation was noted in respect to the dorsal outline and gibbosity. The smaller shells show a slight semi-elliptical outline, a very modest commissure plication, and convexity; however, there seems to be a graduation in the larger shells toward greater gibbosity, more pentagonal outlines, and distinct anterior undulations. This pentagonal outline could be developed as the shells become more gibbose and the plication intensified, drawing in the anterior lateral margins and causing them to flatten in dorsal profile.

The Iowa form *Athyris vittata randalia* does have a slightly different dorsal profile and fold development; however, the variations noted above in the Wisconsin forms seem to minimize this difference. The Wisconsin specimens can be separated from *A. vittata brandonensis* Stainbrook, 1942, because of the stronger fold and sulcus of that form, and from *A. vittata buffaloensis* because of the larger size and more extended anterior margin of that species. *A. nuculoidea* Cooper, 1945, can be distinguished because of its short slightly extended fold. The Wisconsin forms can be separated from *A. vittata* and *A. vittata ovata* Fenton, 1935, due to their stronger folds and distinct lateral profiles.

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EXPLANATION OF PLATE 6

FIGS. 1–6. *Athyris vittata randalia* Stainbrook, 1942; 1–3, brachial, anterior, and lateral views of large shell, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #16602, ×1.8; 4–6, brachial, anterior, and lateral views of immature shell, from same locality, writer's collection #A–21, ×1.8; p. 286.

7–9. *Cyrtina triquetra* (Hall), 1858; 7–9, brachial, anterior, and lateral views, Berthlet Member, Milwaukee Formation, locality 3, M.P.M. #365, ×1.8; p. 288.

10, 11. *Cyrtina umbonata* (Hall), 1858; 10, 11, brachial and lateral views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$16491_5$, ×1.8; p. 288.

12, 13. *Cryptonella?* aff. *C. reimanni* Cloud, 1942; 12, 13, lateral and brachial views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$16452_{13}$, ×1.8; p. 289.

14–17. *Cranaena cooperi* Cloud, 1941; 14–16, brachial (showing color pattern), lateral, and anterior views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$385_4$, ×1.3; 17, brachial view of small shell, from same locality, M.P.M. #$16453_5$, ×2.7; p. 290.

18, 19. *Cranaena* cf. *C. lincklaeni* (Hall), 1860; 18, 19, lateral and brachial views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$16453_8$, ×1.8; p. 292.

20, 21. *Cranaena subovata* Savage, 1921; 20, 21, brachial and lateral views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$16453_9$, ×1.8; p. 292.

22–25. *Cranaena thomasi* Stainbrook, 1941; 22–25, lateral, anterior pedicle (showing color pattern), and brachial views, Lindwurm Member, Milwaukee Formation, locality 3, M.P.M. #$385_2$, ×1.8; p. 293.

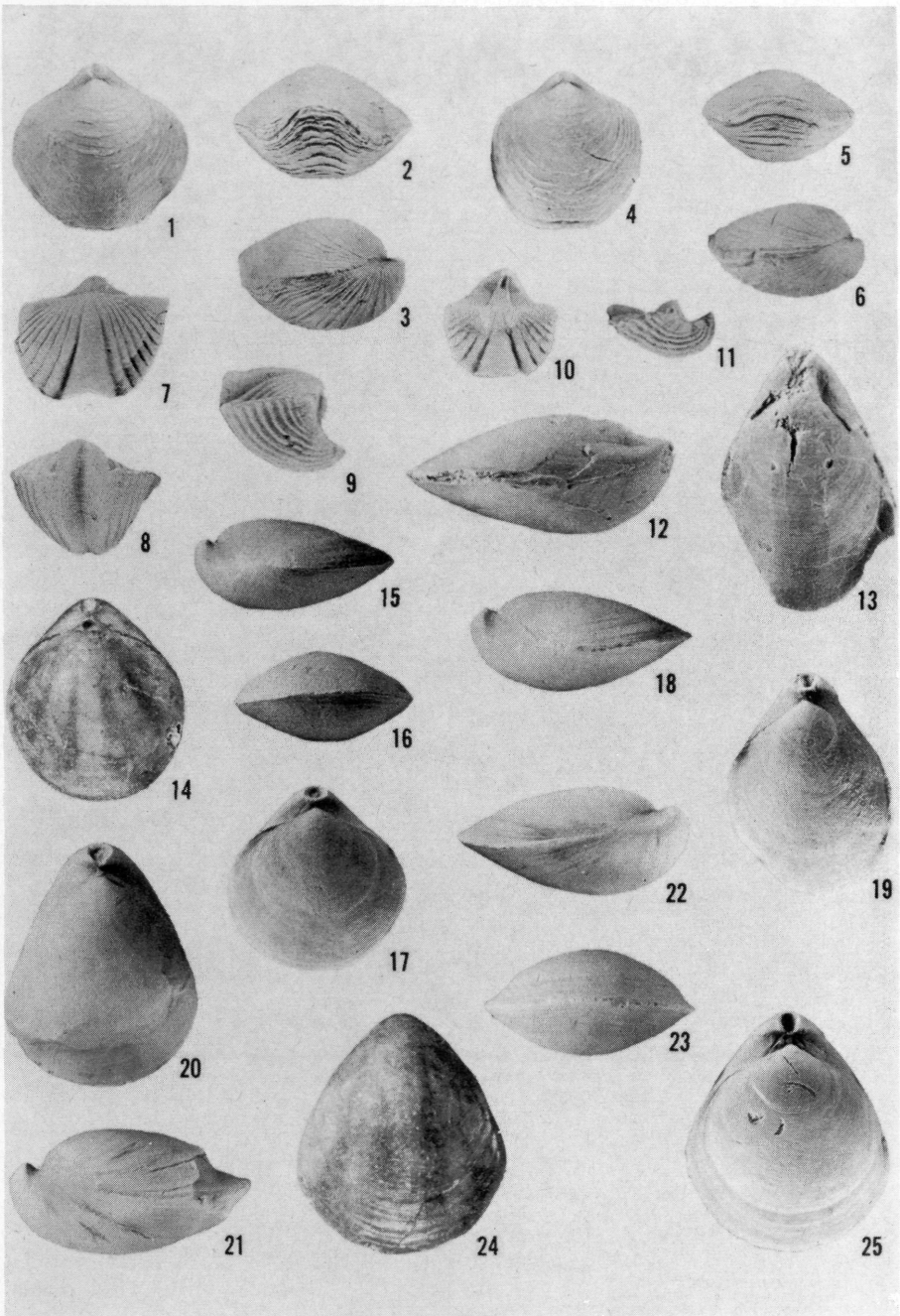


PLATE 6

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation of Estabrook Park, Milwaukee, and the Lake Church Formation at Lake Church, Wisconsin.

Catalogue specimens: Collections of the writer—#A-21, and M.P.M.—#16602.

## Superfamily PUNTOSPIRACEA Cooper, 1944
## Family CYRTINIDAE Stehli, 1954
## Subfamily CYRTININAE Fredericks, 1912
## *Cyrtina* Davidson, 1858

Type species—*Calceola heteroclita* Defrance, 1827

*Cyrtina* Davidson, 1858, Mon. British Carb. Brachiopoda, Pal. Soc. p. 66; Hall, 1867, Pal. New York. 4: 263–265.

Range: M. Silurian—L. Mississippian

### *Cyrtina triquetra* (Hall), 1858
### Pl. 6, figs. 7–9

*Cyrtia triquetra* Hall, 1858, Geol. Sur. Iowa. 1(2): 513.

*Cyrtina hamiltonensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 75, 76. pl. 15, figs. 7–10.

*Cyrtina triquetra* Stainbrook, 1943, J. Paleontol. 17: 446, 447. pl. 70, figs. 22–29.

Description: Moderate size shells for genus; subquadrate to semielliptical in dorsal outline; hinge line equal to greatest width, ventri-biconvex in lateral profile; beak of pedicle valve generally extends slightly beyond hinge line; anterior commissure moderately uniplicate; greatest height near midlength; pedicle valve strongly convex, greatest convexity at umbo; cardinal area elongate-triangular, at commissure approximately perpendicular to hinge line, becomes concave toward beak; delthyrium covered by rounded deltidial plates near hinge line, open near beak; moderate rounded to subangular sulcus; brachial valve slightly convex; rounded fold begins at beak holding crest of brachial valve nearly straight; some shells show slight depression along crest of fold at or posterior to midlength; margin of brachial valve often flattened; surface marked by subrounded plications, fine, occasionally modest lamellose growth lines, and fine punctae.

Dimensions: Average length 7.1 mm, average width 10.1 mm, average height 7.2 mm, average fold width 4.6 mm, average fold height 1.8 mm; 6–9 plications on each side of fold and sulcus.

Discussion: This small, distinctly subpyramidal shell is very common and distinctive in the Lindwurm Member of the Milwaukee Formation. *Cyrtina triquetra* can be separated from *C. umbonata* of the same member because of its more robust and plicate shells and much less distinctive umbo. A considerable amount of variation was exhibited by these forms, mostly noted in the pedicle valve. Slight wings were developed at one or the other or both cardinal extremities; the angle between the cardinal area and the commissure ranged from slightly acute to obtuse; the beak seldom pointed straight, 40 to 45 per cent were directed right and left respectively. In addition, the sulcus showed a moderate subangular to rounded shape.

These Wisconsin specimens show considerable similarity to *Cyrtina hamiltonensis* Hall, 1867, in general form; however, the absence of a pustullose surface clearly separates *C. triquetra* from that perhaps closely related New York species.

Occurrence: Lindwurm and Berthlet Members of the Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of the writer, M.-D.C. and M.P.M.—#365.

### *Cyrtina umbonata* (Hall), 1858
### Pl. 6, figs. 10, 11

*Cyrtia umbonata* Hall, 1858, Geol. Sur. Iowa. 1(2): 512, 513. pl. 5, figs. 2a-c.

*Cyrtina umbonata* Stainbrook, 1943, J. Paleontol. 17: 446. pl. 70, figs. 12–21.

Description: Moderate size shells for genus; subrectangular to semicircular in dorsal outline, posterior margin straight along hinge line, nearly flat anterior margin; hinge line

equals greatest width; ventri-biconvex in lateral profile; beak of pedicle valve extends strongly beyond hinge line; anterior commissure moderately uniplicate; pedicle valve strongly convex, greatest convexity at exaggerated umbo; cardinal area perpendicular to hinge line, but becomes strongly concave toward suberect beak; delthyrium triangular, covered by curved deltidial plates near hinge line, open near beak; subangular to rounded sulcus; brachial valve depressed convex, slightly flattened near wings; rounded fold begins at beak; surface marked by subrounded plications, fine growth lines occasionally slightly exaggerated, and fine punctae.

Dimensions: Average length 8.0 mm, average width 9.3 mm, average height 5.5 mm, average fold width 3.8 mm, average fold height 1.1 mm; 5–6 plications on each side of fold and sulcus; pedicle valve extends 3–5 mm beyond brachial valve.

*Discussion:* The posteriorly extended pedicle valve easily separates *Cyrtina umbonata* from other similar species in the Wisconsin section. The variation noted in these specimens is similar to that mentioned for *C. triquetra*.

The Middle Devonian form, *Cyrtina umbonata alpenensis* Hall and Clarke, 1894, is generally similar; however, the robust, large size of that form separates it from the Wisconsin specimens. There is also a similarity between *C. plena* Fenton, 1935, and *C. umbonata* in outline and appearance, but the Wisconsin form is smaller and does not possess the slight median furrow described for that species.

Occurrence: Lindwurm Member of the Milwaukee Formation at Estabrook Park Milwaukee.

Catalogue specimens: Collection of M.P.M.—#16491$_5$.

## Suborder TEREBRATULOIDEA Muir-Wood, 1955
## Superfamily TEREBRATULACEA Waagen, 1883
## Family DIELASMATIDAE Schuchert and LeVene, 1929
## Subfamily CRYPTONELLINAE Thomson, 1926
## *Cryptonella* Hall, 1861

Type species—*Terebratula rectirostra* Hall, 1860

*Cryptonella* Hall, 1861, New York St. Cab. Nat. His., Rep. 14: 101–102; Hall, 1867, Paleo. New York. 4: 392–393. pl. 61 figs. 1–8; Cloud, 1942, Geol. Soc. Am., Spec. Paper 38: 127–129. pl. 22, figs. 16–26, pl. 23, figs. 1–21.

Range: Devonian

### *Cryptonella?* aff. *C. reimanni* Cloud, 1942
### Pl. 6, figs. 12, 13

*Cryptonella reimanni* Cloud, 1942, Geol. Soc. Am. Spec. Paper 38: 130, 131. pl. 23, figs. 9–18.

Description: Shell moderate size, greatest height posterior to midlength; ventri-biconvex, greatest convexity at umbo of pedicle valve, subovate in dorsal outline, greatest width anterior to midlength; anterior margin slightly sinuate; pedicle valve strongly convex; pedicle area badly crushed, cardinal margin terebratuloid, beak prominent, suberect to straight, foramen moderate size, pointing slightly anterior, no significant lateral thickening, permesothyroid, deltidial plates almost straight, poorly defined palintrope, beak ridges round; brachial valve gently convex, seemingly overlaps pedicle valve along anterior lateral margin; apex with slight linguloid extension; surface ornamented by fairly regular concentric growth lines and fine punctae.

Dimensions: Length 18.7 mm, width 13.2 mm, height 12.0 mm.

Discussion: Due to the similarity in general outline and description, this specimen is tentatively placed under this genus until further material can be studied which may clarify its true taxonomic relationship. Being represented by a single specimen in poor condition, no attempt was made to investigate the internal characteristics. The foramen appears to be permesothyroid; however, the shattered condition of the cardinal area does not allow for a definite conclusion. The pedicle valve is more convex than *Cryptonella reimanni*, more closely approaching *C. planirostra* in this respect. However, the Wisconsin form differs more distinctly from *C. planirostra* in having a relatively less convex brachial valve and a generally narrower shell.

Occurrence: Lindwurm Member of the Milwaukee Formation along the Milwaukee River in Milwaukee County.

Catalogue specimen: One specimen from M.P.M.—#16452$_3$.

## Subfamily CRANAENINAE Thomson, 1926

### *Cranaena* Hall and Clarke, 1893

Type species—*Terebratula romingeri* Hall, 1863

*Cranaena* Hall and Clarke, 1894, pal. New York. 8(2): 297. pl. 80, figs. 13–19, fig. 215; Cloud, 1942, Geol. Soc. Am. Spec. Paper 38: 132–140. pl. 23, figs. 24–31, pl. 24, figs. 1–33.

Diagnosis: Terebratuliform, small to moderate shells marked by fine punctae and growth lines, on occasion median fold and sulcus; foramen large, distinctly permesothyroid; loops short not reaching midlength of valve with ventral, transverse band; no median septa; moderate, well developed central lamellae.

Discussion: Since the report by Cleland (1911) concerning the Wisconsin Devonian fauna, several important contributions to the study of *Cranaena* have helped to clarify the understanding of this genus. The work by Cloud (1942) has clearly placed all the known terebratuloids from the Wisconsin section, with perhaps one exception, under the genus *Cranaena*. Serial sections of eight specimens of four species at 0.5-mm intervals proved only that the shells had strong, moderate, dental lamellae, moderate low cardinal plates, and short loops (fig. 4). Dolomitizatation and crystal growth have destroyed most of the internal characters. Radial color patterns as mentioned by Cloud (1941) were noted on several specimens of two species from the Wisconsin material. The patterns are very similar to those reported by Cloud (1941) and Stainbrook (1941), which have been referred to original coloration and direct alignment with the pallial sinus impressions, and may be due as Cloud suggested to a physiological reaction related to the function of the sinuses.

Range: M. Devonian—Mississippian.

### *Cranaena cooperi* Cloud, 1941

Pl. 6, figs. 14–17

*Cranaena iowensis* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 72. pl. 13, figs. 8–9 (not 10–11).

*Cranaena cooperi* Cloud, 1941, Am. J. Sci. 239: 905. pl. 1, figs. 17–19.

Description: Shell moderate size, greatest width slightly anterior to midlength, ventribiconvex, greatest height posterior to midlength; subelliptical to subround in dorsal outline, straight cardinal margins, lateral and anterior margins regularly rounded; anterior commissure very slightly sinuate to rectimarginate; margins thin to slightly thickened; pedicle valve moderately convex; cardinal margin terebratuloid, beak prominent, suberect; foramen moderate size, subovate, permesothyroid; deltidial plates concave, palintrope short, beak ridges round to subangular; brachial valve gently convex; surface marked by fairly regular growth lines; numerous punctae; dark radial color bands, beginning at umbo extending anteriorly, color bands present on both valves.

Dimensions: Average pedicle valve length 16.4 mm, average brachial valve length 14.5 mm, average width 14.2 mm, average height 7.9 mm; color bands 4 mm wide near anterior margin.

Discussion: This species is distinguished by its subelliptical to subcircular outline, and moderately convex lateral profile. Many variations are noticeable, such as the shift of the foramen to a nearly mesothyroid position, the degree of angularity of the beak ridges, the distinct to indistinct palintrope, the possession of radial color bands (similar bands also appear on other species), and the distinctly concave to almost flat deltidial plates. There seems to be a considerable amount of integration of general external characteristics within the Wisconsin assemblage, and the internal characters are not well enough preserved to make significant separations. Therefore, general shell shape becomes the most useful single characteristic in separating species. *Cranaena iowensis* differs from *C. cooperi* in having a stronger and more equally biconvex lateral profile, a subpentagonal outline, and an incurved rather

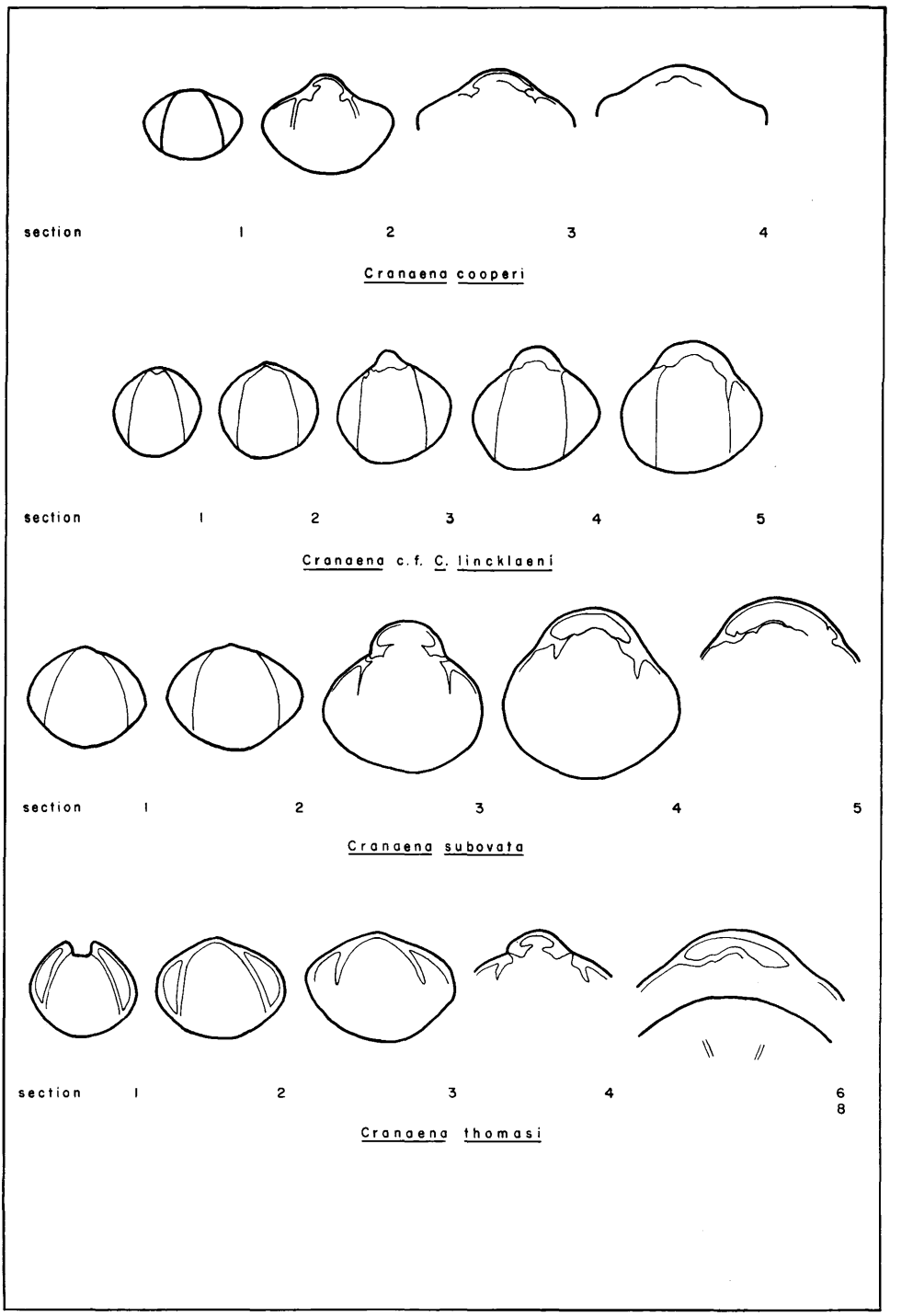


FIGURE 4. Serial sections of the genus *Cranaena*, at 0.5-mm intervals, figs. ×2.

than suberect beak. *C. cooperi* can be separated from *C. radiata* Cooper and Cloud, 1938 in having a more subelliptical dorsal outline, and a more equally biconvex lateral profile.

Occurrence: Lindwurm Member of the Milwaukee Formation along the Milwaukee River at Estabrook Park, Milwaukee.

Catalogue specimens: Seventeen specimens from M.P.M.—#$385_4$, #$16453_5$.

## *Cranaena* cf. *C. lincklaeni* (Hall), 1860
Pl. 6, figs. 18, 19

*Terebratula lincklaeni* Hall, 1860, New York St. Cab. Nat. Hist. Rep. 13: 88.
*Cryptonella lincklaeni* Hall, 1861, New York St. Cab. Nat. Hist. Rep. 14: 101.
*Cryptonella? lincklaeni* Hall, 1867, Pal. New York. 4: 397. pl. 60, figs. 49–65.
*Eunella lincklaeni* Hall and Clarke, 1894, Pal. New York. 8(2): 290. pl. 80, figs. 28–32.
*Eunella lincklaeni* Cleland, 1911, Wis. Geol. and Nat. Hist. Surv. Bull. 21: 72.
*Cranaena lincklaeni* Cloud, 1938, Geol. Soc. Am., Spec. Paper 38: 134–136.

Description: Shell moderate size, greatest width anterior to midlength, shell slightly ventri-biconvex in lateral profile, greatest height posterior to midlength; subelliptical to subovate in dorsal outline, cardinal margin slightly concave, lateral and anterior margins gently to regularly convex; anterior commissure slightly sinuate to rectimarginate; margins generally thin; pedicle valve slightly more convex, cardinal margin terebratuloid, beak prominent, suberect, beak ridges moderately strong, round to subangular; palintrope moderate to very distinct, deltidial plates slightly concave; foramen moderate size, subovate, permesothyroid to nearly mesothyroid; brachial valve gently convex; surface marked by fine growth lines and numerous punctae.

Dimensions: Average pedicle valve length 17.1 mm, average brachial valve length 15.1 mm, average width 13.1 mm, average height 8.1 mm; palintrope 3–5 mm long.

Discussion: This group of shells can be distinguished from *Cranaena cooperi* only by its more extended beak and more elliptical outline. The same variations as mentioned in the discussion of *C. cooperi* apply to this assemblage. *C. thomasi* Stainbrook, 1941, also resembles *C.* cf. *C. lincklaeni* in lateral profile, but differs in being relatively wider in respect to length, and has a broader beak and palintrope.

Occurrence: Lindwurm Member of the Milwaukee Formation along the Milwaukee River, Milwaukee.

Catalogue specimens: Collections of M.P.M.—#$16453_8$.

## *Cranaena subovata* Savage, 1921
Pl. 6, figs. 20, 21

*Cranaena subovata* Savage, 1921, Ill. Acad. Sci. 14(1): 7. pl. 2, figs. 9, 10.
*Cranaena subovata* Stainbrook, 1941, J. Paleontol. 15: 45. pl. 7, figs. 6–8, text fig. 9.

Description: Shells moderate to large, greatest width very near anterior margin; subovate in dorsal outline, cardinal and lateral margin very slightly curved, anterior lateral margin sharply convex leading to regularly rounded anterior outline; ventri-biconvex; anterior commissure slightly sinuate to rectimarginate; pedicle valve strongly convex, cardinal margin terebratuloid, beak very prominent, suberect, beak ridges subround; distinct moderate palintrope, deltidial plates concave; foramen moderate size, unthickened walls, permesothyroid; brachial valve moderately convex; surface marked by fine to moderate growth lines and numerous punctae.

Dimensions: Average pedicle valve length 19.3 mm, average brachial valve length 16.5 mm, average width 16.3 mm, average height 9.8 mm.

Discussion: These forms are most distinctive in their moderately strong convexity and near anterior position of the greatest shell width. The external characteristics show the variations mentioned in the discussion of *Cranaena cooperi* to a slightly lesser degree, which may be due to the lack of individuals. *C. subovata* is very close in general description to *C. radiata*, though that form has a more convex brachial valve and a distinctive erect beak. *C. subcylindrica* Cooper and Cloud, 1938, also has a similar profile, but differs in its more elongate

outline and greater length-to-width ratio. In outline and description, *C. maculata* is similar to *C. subovata*, but has a uniplicate anterior commissure and radial spots, which may be of no specific value.

Occurrence: Lindwurm Member of the Milwaukee Formation along the Milwaukee River, Milwaukee.

Catalogue specimens: Collections of M.P.M.—#16453$_9$.

## *Cranaena thomasi* Stainbrook, 1941
Pl. 6, figs. 22–25

*Cranaena thomasi* Stainbrook, 1941, J. Paleontol. 15: 54. pl. 7, figs. 9, 10, 14, 15.
*Cranaena thomasi* Cloud, 1941, Am. J. Sci. 239: 906. pl. 1, figs. 13–15.

Description: Shell moderate size, greatest width near anterior margin; subovate to ovate in dorsal outline, cardinal and lateral margins very gently curved, posterior lateral margin strongly convex leading to slightly sharpened regular anterior outline; ventri-biconvex; anterior commissure very slightly sinuate to rectimarginate; margins thin; pedicle valve strongly convex, cardinal margin terebratuloid, beak very prominent, suberect, beak ridges rounded to subrounded; broad moderately distinct palintrope, deltidial plates concave; foramen moderate size, subovate, very slight wall thickening, permesothyroid; brachial valve gently convex; surface ornamented by fairly regular fine concentric growth lines, numerous punctae, and on occasion dark radial color bands appear beginning at umbo becoming 3 mm wide near anterior margin on both valves.

Dimensions: Average pedicle valve length 21.8 mm, average brachial valve length 19.2 mm, average width 18.7 mm, average height 9.6 mm.

Discussion: These forms are distinctive because of their anteriorly broad outline, moderately convex profile, and nearly straight lateral margins. In this species, dark radial color bands become apparent which have a very similar appearance to those found on *Cranaena cooperi*. *C. thomasi* is also similar to *C. cooperi* in general lateral profile, but it is slightly less equally biconvex and is more ovate in dorsal outline. *C. thomasi* is similar to *C. subovata* in dorsal outline, but has its greatest width more posteriorly, and is significantly less convex than that form. The Wisconsin form can be distinguished from *C. radiata* Cooper and Cloud, 1938, by having a stronger width to length ratio, a suberect rather than an erect beak, and a less equally biconvex shell.

Occurrence: Milwaukee Formation at Estabrook Park, Milwaukee.

Catalogue specimens: Collections of M.P.M.—#385$_2$.

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